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op. 2

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(English Edition)

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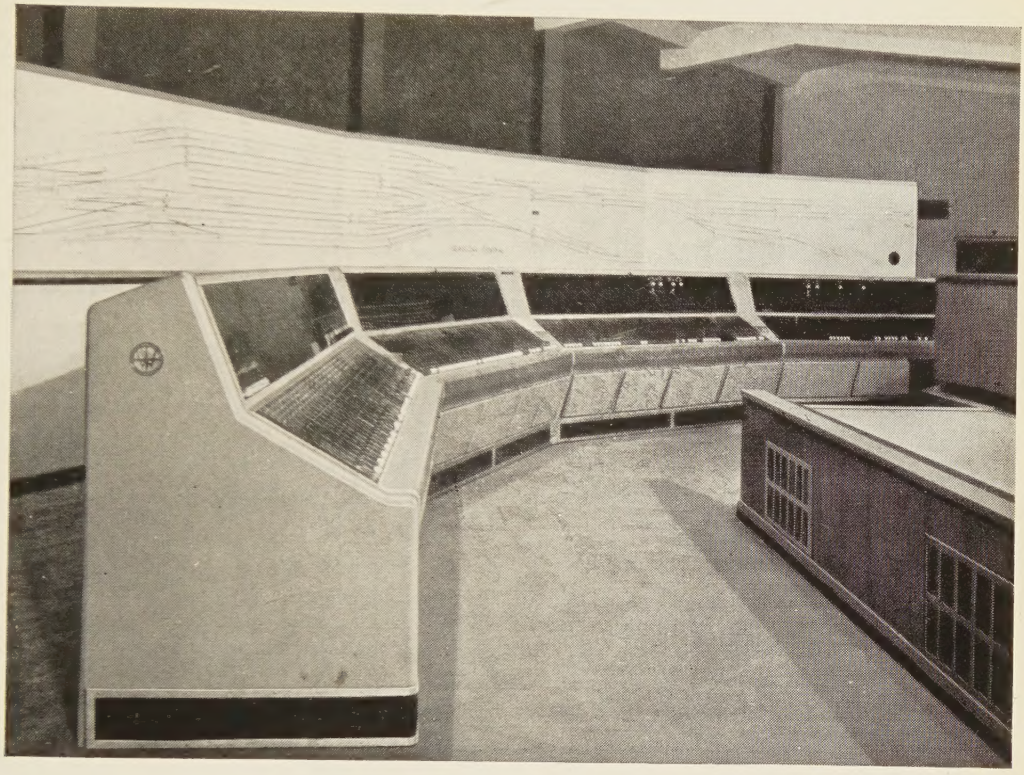

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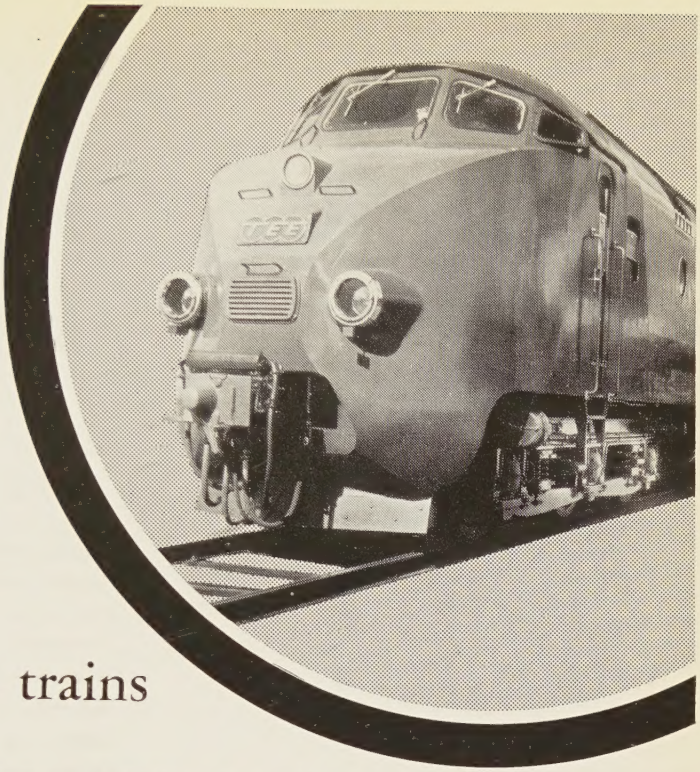

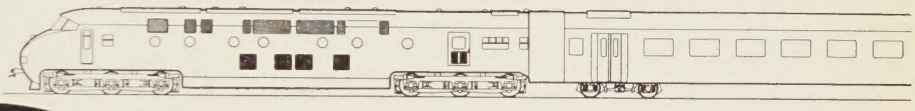

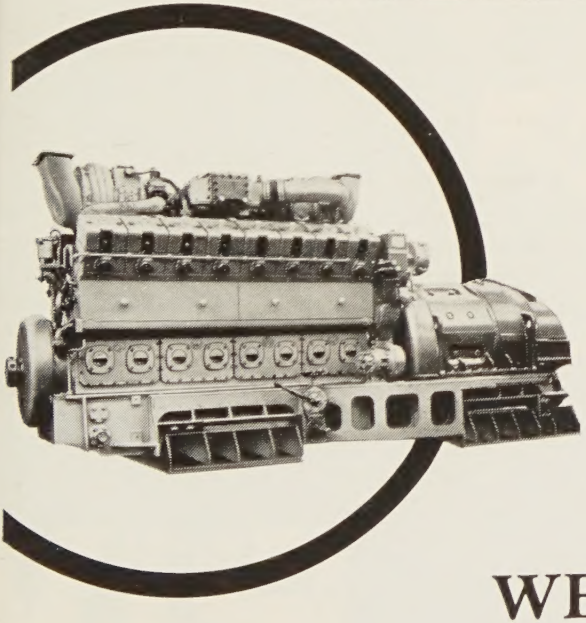

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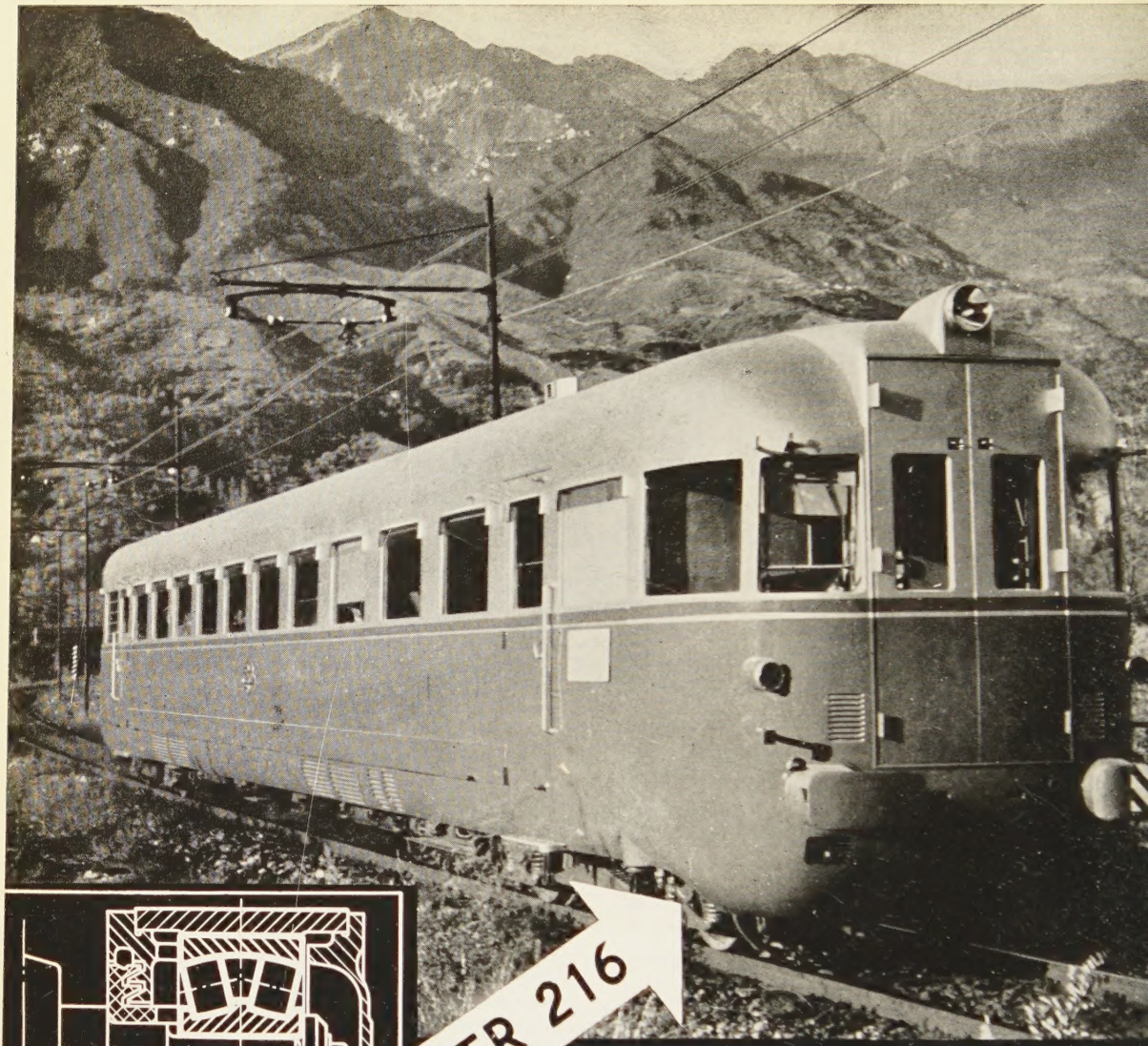

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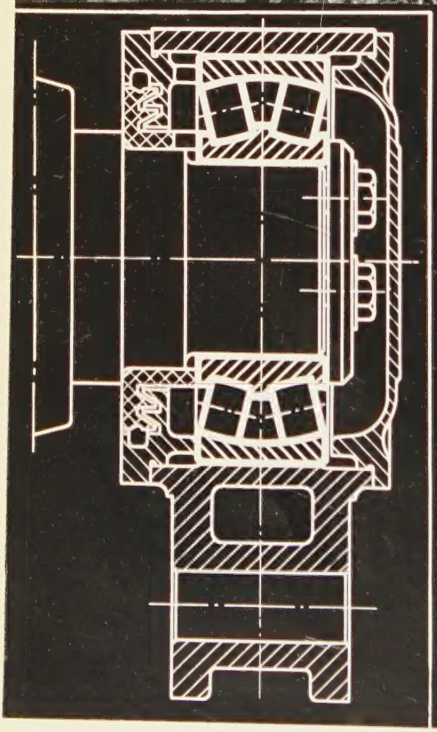

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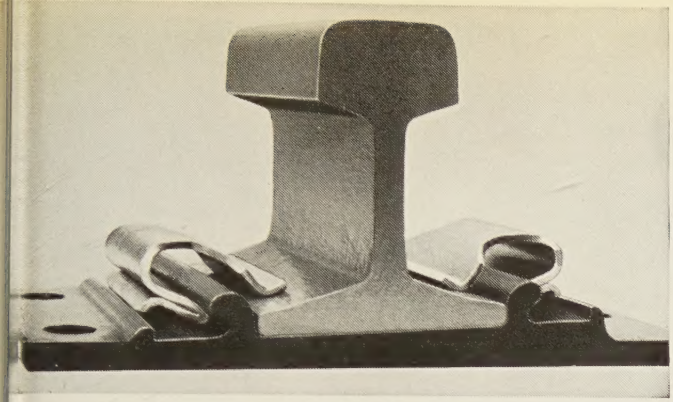

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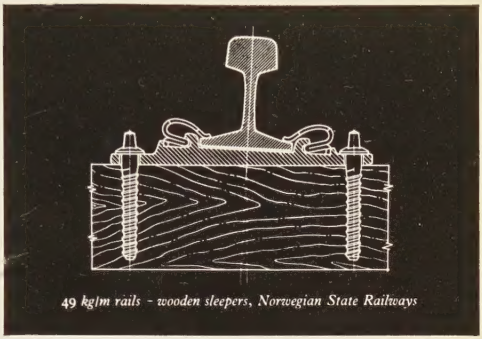
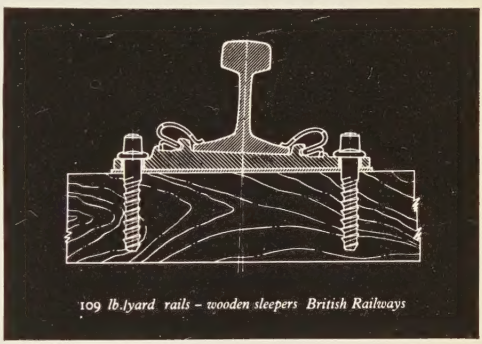


49 kg/m rails - wooden sleepers, Norwegian State Railways



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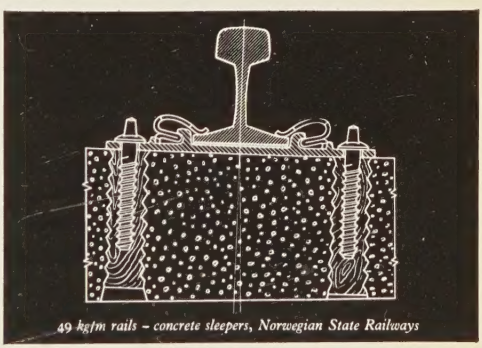

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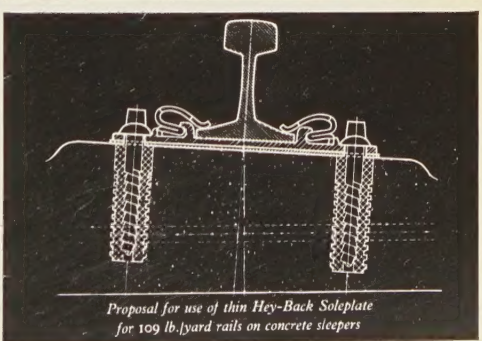

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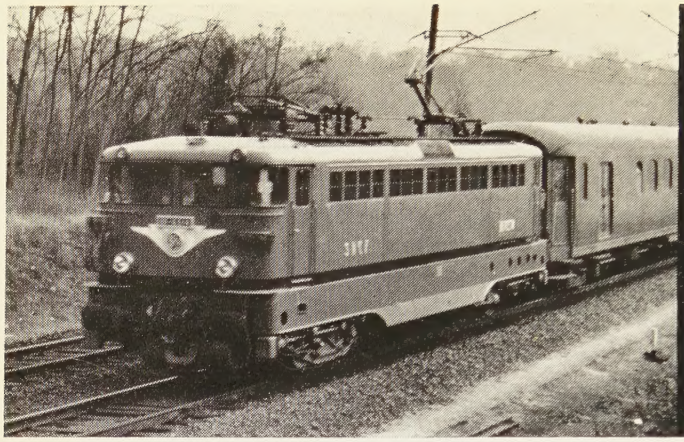

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OF THE

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Bulletin of the International Railway Congress Association

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .144 .2 & 656 .222 .1]

Speed of trains in curves,

by A. JACOPS,

Chief Civil Engineer, Belgian National Railways.

A. GENERAL OBSERVATIONS ON SUPERELEVATION

It is generally assumed that the theoretical cant of standard gauge track in curves is calculated from the formula :

$$h = \frac{V^2}{85\,R} = 0.0118\,\frac{V^2}{R} \qquad (1)$$

where :

h = superelevation (in m),

V = speed of the train (in km/h),

R = curve radius (in m).

The coefficient 85 which takes into account the track gauge and the gravity constant, is subject to slight variations depending on the precise value assumed for the distance between the running treads.

But there is also general agreement that, in practice, this formula cannot be regarded as wholly satisfactory. This is due to two circumstances :

1° a track is normally used by trains of greatly different speeds : a track should therefore, in theory, have a variable cant which is, of course, impracticable;

2° when the formula has been solved for V, i.e. when the speed admissible for a curve of given radius and cant has been calculated from it, it is nevertheless found possible to work at a considerably higher speed; in particular, if the cant is zero — as is usually the case in the deviated line of points and slip points — the strict application of the formula would yield $V = 0$ so that, theoretically, all traffic would have to be stopped whereas, in fact, speeds of at least 30 or 40 km/h have always been authorized over points and crossings.

One has therefore gone over to adding, to the second member of equation (1), a negative and sometimes variable corrective term so that the equation assumes the following form :

$$h = \frac{V^2}{85\,R} - a. \qquad (2)$$

The value a is conventionally known as « cant deficiency »; its physical origin is the lack of balance of part of the centrifugal force which is encountered when a vehicle negotiates a curve.

We shall here refrain from discussing

this formula which was debated at the Paris Congress in 1937 (cf. « Bulletin » of February 1937). In the following, the term a is assumed to be constant, and equal to 0.09 m.

This time, the equation can be solved in respect of V without the risk of obtaining an unrealistic result :

$$V = \sqrt{85\,R\,(h + a)}. \qquad (3)$$

Even if $h = 0$, one obtains a reasonable result for V, and even negative values of h are admissible within certain limits.

Formulas (2) and (3) have been adopted in numerous countries. To our knowledge, however, there are but few administrations which distinguish between curves with transition sections, and curves without them. True, all the regulations nowadays prescribe the use of transition curves at the ends of curves, and between curves with curvature in the same direction but with different radii. But there are, in practice, numerous cases where a curve is not provided with transition sections, and these cases are undoubtedly rather undesirable. They are, for instance, encountered where a through track passing through a station is slightly deviated by minor curves inserted between groups of points and crossovers, or bridges, and the provision of transition curves is consequently precluded by lack of space. A more complicated case arises where, despite the absence of transition curves, the track is given a cant, which may happen in exceptional cases. There are the cases, too, of bifurcations and crossovers.

To discuss this question, equation (3) may be transformed into :

$$\frac{V^2}{R} = 85\,h + p. \qquad (4)$$

where the term p, equal to 85 a, stems from the assumed cant deficiency and is directly proportional to the non-balanced part of the centrifugal force as well as to the transverse thrust exerted by the wheels on the outer line of rails, ignoring the guiding force which does not enter into consideration here. It is known that, for $a =$ 0.09 m, this thrust is equal to $\frac{0.09}{1.50} = 0.06$, i.e. to 60 kg per tonne of axle load. For simplicity's sake, the term p will, in the following, simply be called the « thrust », it being understood that its value is merely proportional to the thrust (viz., 127 times as great).

In applying formula (4), p is always given a maximum value p_M so that the equation can be used to work out the permissible maximum speed. Except on sections where a speed restriction is in force, the speed V rarely attains that value, and the true value of the thrust can be calculated by solving equation (4) in respect of p. This value must thus always be lower than p_M or, at the most, be equal to it. Equation (4) can therefore be replaced by the relation :

$$\frac{V^2}{R} \leq 85\,h + p_M. \qquad (5)$$

If a is assumed to be 0.09 m, the maximum thrust thus becomes $p_M = 7.6$, and this is the value assumed in the following. Some administrations work with $a = 0.10$ m, i.e. $p_M = 8.5$.

B. CURVED TRACK WITH A MATHEMATICAL DISCONTINUITY

1. — General.

If the arc of a circle is linked to another circular arc or to a straight line by means

of a transition curve, the mathematical continuity of the alignment is regarded as ensured. This is not the case if the transition curve is omitted. We shall first of all assume the most general case of two co-tangential circular arcs, with the radii R_1 and R_2, curving in the same direction, and shall adopt the convention that R_2 is always greater than R_1 (fig. 1 *a* and 2 *a*).

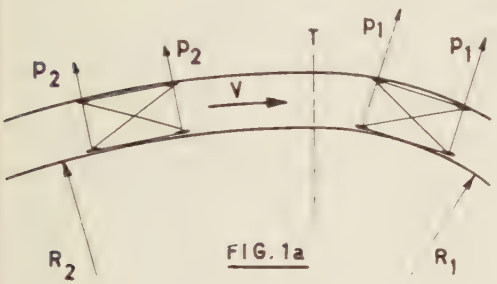


FIG. 1a

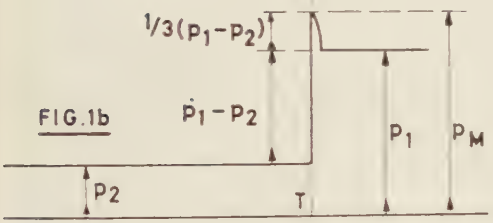


FIG. 1b

When an axle passes over a given point of this kind, it is subjected to a more or less violent lurch due to the variation in the thrust which is exerted on it transversely. Whilst the axle, when running on the section with the radius R_1, is subjected to a thrust p_1, it is subjected to a thrust p_2 when running on the curve with the radius R_2. The variation in thrust amounts to $p_1 - p_2$ or $p_2 - p_1$, depending on the direction of running.

But, irrespective of the latter, the immediately occurring change of pressure at the contact with the rail gives rise to a phenomenon resembling that of an abrupt load application, a notion studied in the theory of the strength of materials, and resulting in a momentary increase in the effect of the forces actually at play. In theory, this effect is to double the stresses calculated for the static condition. Here, taking into account the elasticity present not only in the vehicle suspension but also, to some extent, in the track, and also

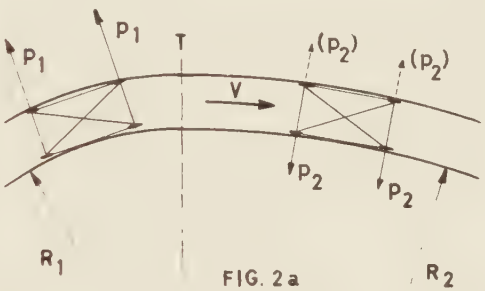


FIG. 2a

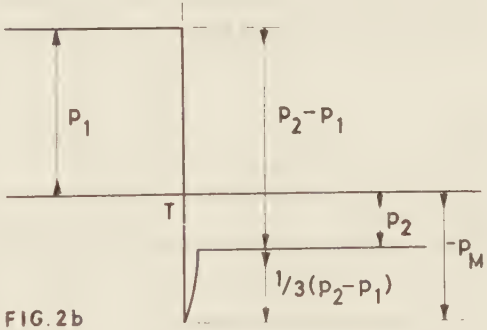


FIG. 2b

in view of the fact that the different axles of a vehicle do not attack the point of discontinuity simultaneously but successively, the momentary increase in the variation of the force may be assumed to be not greater than one-third of the latter.

2. — **Running from the R_2 curve to the R_1 curve.**

If, at point T in figure 1, an axle passes from the R_2 curve to the R_1 curve, the variation in thrust amounts to $p_1 - p_2$, which is a positive quantity. Immediately ahead of this point (cf. fig. 1 *b*), the thrust is p_2; immediately beyond that point, it amounts to :

$$p_2 + \frac{4}{3}(p_1 - p_2) \quad \text{or} \quad \frac{4}{3}p_1 - \frac{1}{3}p_2 \qquad (6)$$

before it drops to p_1. But on no account must the value of (6), however momentary it may be, be allowed to exceed p_M.

By substituting for p_1 and p_2 the values obtained from (4), one obtains :

$$V^2\left(\frac{1}{R_1} - \frac{1}{4R_2}\right) \leqslant 64h + \frac{3}{4}p_M \qquad (7)$$

where h is the cant at the common point T of the two arcs, and has a given and known value, even if the cant varies in the vicinity of the tangential point. Under the assumptions made above, one obtains :

$$\frac{3}{4}p_M = 5.7.$$

Special cases of interest.

a) If, in formula (7), R_2 becomes infinite, which corresponds to the case of a vehicle entering a curve, one obtains :

$$\frac{V^2}{R_1} \leqslant 64h + \frac{3}{4}p_M \quad \text{or} \quad 64h + 5.7. \qquad (8)$$

It will be seen that the second member is smaller by one quarter than it would be according to formula (5). If, for a given radius and cant, the speed is worked out in each case, the value obtained from formula (8) amounts to no more than 0.866 of the value obtained from formula (5), corresponding to a reduction of 13 %.

It is therefore desirable to provide a certain superelevation at the entrance point of a curve although, if it is possible to provide a cant, it is generally also possible to provide a transition curve.

In any case, the cant must remain below a certain limit value so as to prevent the thrust p on the straight track just ahead of point T from exceeding a permissible maximum value. Reverting to formula (5), the axle which has not yet entered the curve proper is merely affected by the radius R which, in this case, is infinite :

$$85h \geqslant -p_M + \frac{V^2}{\infty} \qquad (9)$$

hence :

$$h \leqslant \left|\frac{p_M}{85}\right| \qquad (10)$$

i.e. 0.09 m (absolute value).

h must therefore remain smaller than 0.09.

b) The most commonly encountered special case is that of $h = 0$, when :

$$\frac{V^2}{R} \leqslant \frac{3}{4}p_M \quad \text{or} \quad 5.7 \qquad (11)$$

hence : $$V \leqslant 2.4\sqrt{R}. \qquad (12)$$

c) If the direction of the curve with the radius R_2 is changed, i.e. if one has to deal with an *S*-curve (again without transition sections), and if the vehicle moves from the curve with large radius into that with small radius, one obtains from formula (7), by changing the sign of R_2 :

$$V^2\left(\frac{1}{R_1} + \frac{1}{4R_2}\right) \leqslant 64h + \frac{3}{4}p_M. \qquad (13)$$

In view of the fact that, in this case, h would normally be zero, one obtains :

$$V^2\left(\frac{1}{R_1}+\frac{1}{4\,R_2}\right)\leqslant\frac{3}{4}p_M \quad \text{or 5.7.} \quad (14)$$

The most frequent case is that of two curves with equal radius, i.e. :

$$\frac{V^2}{R}\leqslant\frac{3}{5}p_M \quad \text{or 4.6} \quad (15)$$

whence :

$$V\leqslant 2.1\sqrt{R}. \quad (16)$$

3. — **Running from the R_1 curve to the R_2 curve.**

It is also necessary to contemplate the direction of running from a curve with small radius to a curve with large radius. In this case, the variation in thrust becomes p_2-p_1, i.e. a negative quantity being directed towards the centre of the curve (since, in accordance with the convention here adopted, the absolute value of p_1 is always greater than that of p_2). It can, incidentally, not be ruled out that the final value of p_2 in itself may become negative. In any case, the maximum thrust p_M which must not be exceeded is now also directed towards the centre of the curve, and must thus be taken as negative.

In the circumstances, and following the same argument as before (cf. figs. 2 *a* and 2 *b*), one obtains :

$$p_1+\frac{4}{3}(p_2-p_1) \quad \text{or}$$

$$\frac{4}{3}p_2-\frac{1}{3}p_1\geqslant -p_M. \quad (17)$$

hence :

$$V^2\left(\frac{1}{R_2}-\frac{1}{4\,R_1}\right)\geqslant 64\,h-\frac{3}{4}p_M. \quad (18)$$

Special cases of interest.

a) If, in formula (18), R_2 becomes infinite, which corresponds to the case of a vehicle leaving the curve, one obtains :

$$\frac{V^2}{R_1}\leqslant -4\times 64\,h+3\,p_M \quad \text{or}$$

$$-256\,h+22.8. \quad (19)$$

This formula must be compared with (5), which applies to the curve proper. The second members are equal if $h = 0.045$ m. For a lower cant, (5) yields a higher value than (19), which means that there is, in this case, strictly speaking never any need for a transition curve. With a higher cant, the opposite is the case, and formula (19) must be allowed to govern conditions at the exit from the curve, though only up to a value of $h = 0.09$ m, as the second member would then become zero and the result negative, which is obviously unrealistic.

Formula (19) must also be compared with (8), as it is always possible that the direction of running of the trains might be reversed, and that the exit point of a curve becomes the entrance point. For a cant smaller than 0.053 m formula (8) must be followed. For a greater cant (up to the maximum of 0.09 m), it is again formula (19) that must be observed.

b) The most frequent case is obviously again that of $h = 0$:

$$\frac{V^2}{R}\leqslant 3\,p_M \quad \text{or 22.8} \quad (20)$$

hence :

$$V\leqslant 4.8\sqrt{R}. \quad (21)$$

This formula appears to yield a more favourable value than formula (12). Norm-

ally, however, it is not possible to make use of it, since the speed is limited from the outset by the maximum speed which, according to formula (5), is permissible in the curve proper (h again being zero).

But a comparison of formulas (21) and (12) will make it clear why, other circumstances being equal, leaving the curve always appears to be « easier » than entering the curve.

c) Also in this case, one might consider the special case of the *S*-curve, it being understood that the movement takes place from the curve with small radius to the curve with large radius. Formula (18) then becomes :

$$V^2\left(-\frac{1}{R_2}-\frac{1}{4R_1}\right)\geqslant 64h-\frac{3}{4}p_M. \quad (22)$$

and, as the cant will normally be zero :

$$V^2\left(\frac{1}{R_2}+\frac{1}{4R_1}\right)<\frac{3}{4}p_M \quad \text{or } 5.7. \quad (23)$$

Compared with (14), the parts played by R_1 and R_2 are now reversed. However, as it has been assumed that R_2 is always greater than R_1, the value in brackets is greater in formula (14) than in formula (23), and the resulting speed is lower in the former case than in the latter.

In the extreme case, where R_2 becomes equal to R_1, formulas (14) and (23) are identical.

C. GENERAL DISCUSSION

Before following up the application of the theory to other cases of interest, it appears desirable to examine the results obtained with the aid of graphs.

First of all, one might, by regarding

$$\frac{V^2}{R_1}, \quad \frac{V^2}{R_2} \quad \text{and} \quad h$$

as independent variables, resort to a three-dimensional presentation. But such a presentation, reduced to the two dimensions of the paper, would not be very useful in practice. It would appear to be preferable to use a two-dimensional presentation by eliminating the h axis or, in other words, by treating h as a parameter. This has, in fact, been done in figure 3, where a value of $p_M = 7.6$ has been assumed.

The strongly inclined straight lines are those representing equation (7) without the inequality sign (passing from a curve with large radius to one with small radius), whilst the less strongly inclined straight lines represent equation (18) (passing from a curve with small radius to one with large radius). The figures shown against the straight lines indicate the cant in centimetres. The families of straight lines are limited to the bisectors OB and OB' since, in accordance with our convention, R_2 is greater than R_1. The part of the graph on the side of the negative R_2 values indicates *S*-curves.

To be admissible in practice, a system of values $\left(\frac{V^2}{R_1}, \frac{V^2}{R_2}\right)$ must be located to the left of, or above, a straight line of each family corresponding to the existing or assumed cant. If it is necessary to take both directions of running into account simultaneously, the point on the graph must, at one and the same time, conform to both conditions. In other words, the point must be located within the triangle or quadrilateral formed by the two bisectors and the straight lines of equal cant selected from each family.

Thus, the point marked F will be suitable for cants higher than 4 and lower than

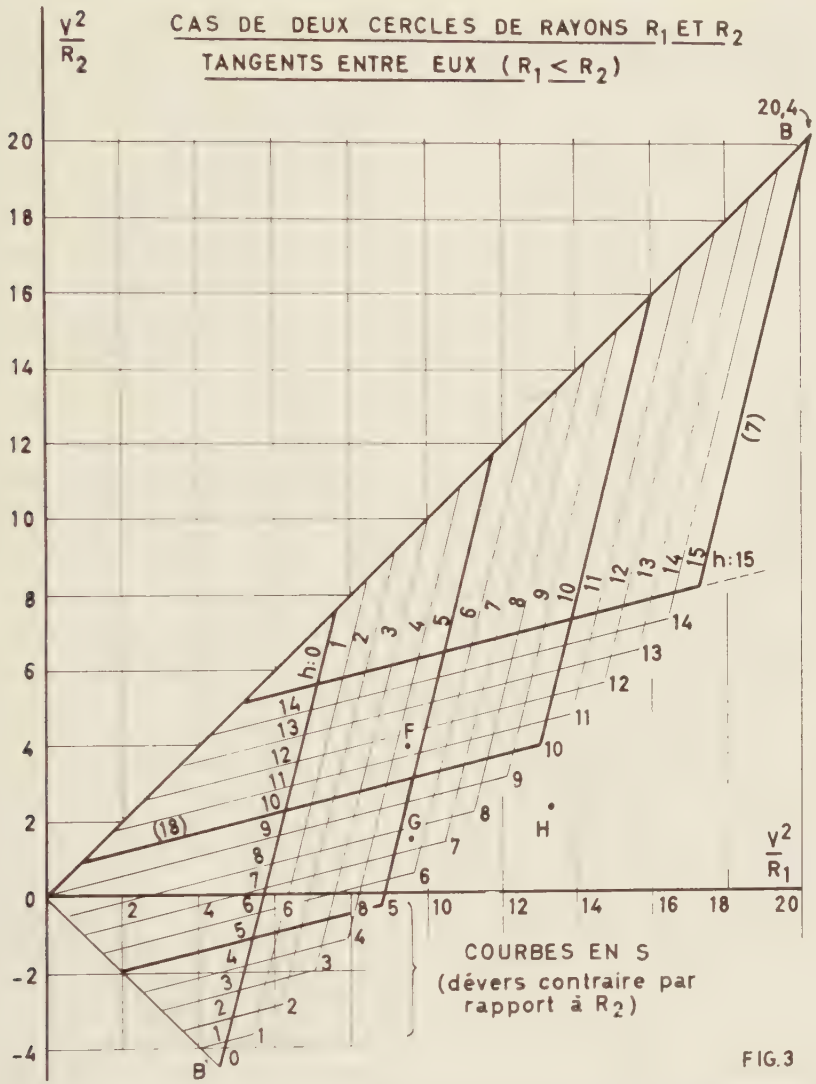


FIG. 3

N.B. — Cas de deux cercles de rayons R_1 et R_2 tangents entre eux = case of two tangential circular arcs with the radii R_1 and R_2. — Courbes en S (dévers contraire par rapport à R_2) = S-curves (cant opposite in relation to R_2).

12 cm, whilst point *G* is only suitable for values of 6 and 7 cm, and point *H* must be ruled out altogether.

Figure 4 has been plotted for curves with a single radius, not provided with transition curves. If we assume that, in the preceding graph, we have actually set up an *h* axis perpendicular to the plane of the paper, the graph will show what happens in the vertical plane of co-or-

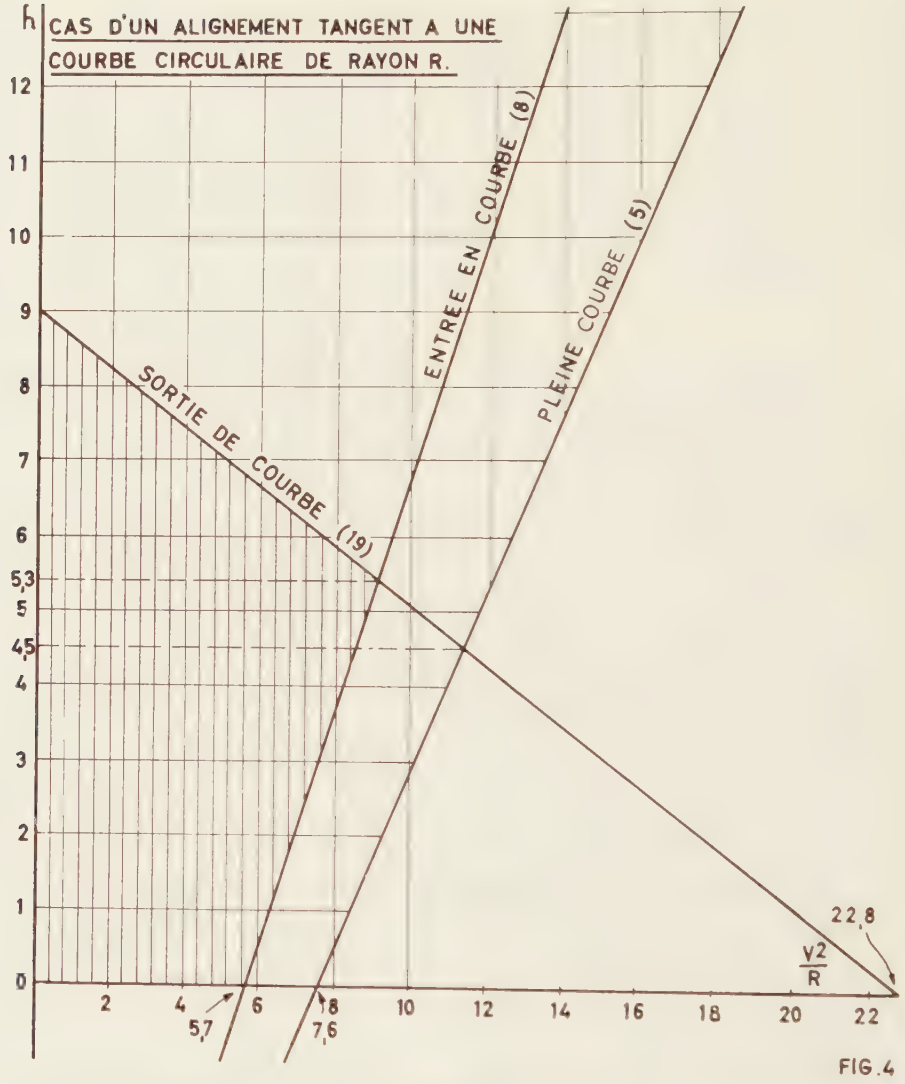


FIG. 4

N.B. — Cas d'un alignement tangent à une courbe circulaire de rayon R = case of a straight tangential to a curve of radius R. — Entrée en courbe = entering the curve. — Pleine courbe = full curve. — Sortie de courbe = leaving the curve.

dinates passing through the $\frac{V^2}{R_1}$ axis. The characteristic straight lines are marked with the number of the equations which they represent.

To be applicable without restriction, a representative point $\left(\frac{V^2}{R},\ h\right)$ must be located within the quadrilateral formed by the straight lines (8) and (19) on the one

hand, and by the axes of the co-ordinates on the other hand.

Like figure 3, this graph shows under what conditions negative cants can be tolerated.

If a point is situated outside the triangles or quadrilaterals described above, this implies that the thrust exceeds the permissible maximum value p_M.

D. INTERRUPTED CURVES

1. — General.

For the purpose of authorizing a maximum speed, it is often necessary to decide how to deal with a curve (of constant or varying radius) interrupted by a short section of straight track, or also with a system of curve and counter-curve, if these curves are not directly contiguous and are not provided with transition curves.

If one tries to interpret the relations established in the foregoing sections, it is found that :

1° the effect of entering a curve is represented by $\frac{V^2}{R}$;

2° the effect of leaving a curve is represented by an expression of similar form but reduced to a quarter, and manifests itself as a lessening of the thrust (negative sign) if the curves are in the same direction, and as an increase in thrust (positive sign) if the curves are in opposite directions;

3° the overall effect is compared with the permissible maximum pressure $\left(\frac{3}{4} p_M \text{ or } 5.7\right)$ taken in the direction towards the outside of the curve (positive direction) if the vehicle runs in the direction in which the curvature becomes sharper (i.e. towards the section with smaller radius), and taken in the direction towards the centre (negative direction) if the vehicle runs in the direction in which the curvature eases (i.e. towards the section with greater radius);

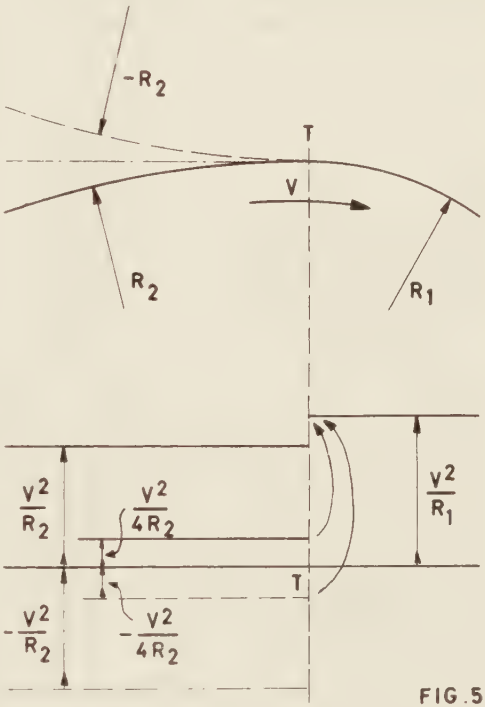


FIG. 5

4° in either case, the permissible thrust is shifted to a higher limit (positive direction) by the effect of the cant which is expressed in the form 64 h.

For contiguous curves, this interpretation is illustrated by figures 5 and 6.

But if the two circular arcs are separated by a straight line, the effect of leaving the curve is reduced and will even tend to

disappear after a certain rather short time t, in accordance with a law which is assumed to be linear and depends on c, a constant denoting the rate of speed at which the thrust decreases.

In figure 7, the letter T marks the exit point of a curve, and T' the entrance point of a following curve which may or may not have the same direction of curvature. Also, let l be the length of the straight section between the curves, and l_M the

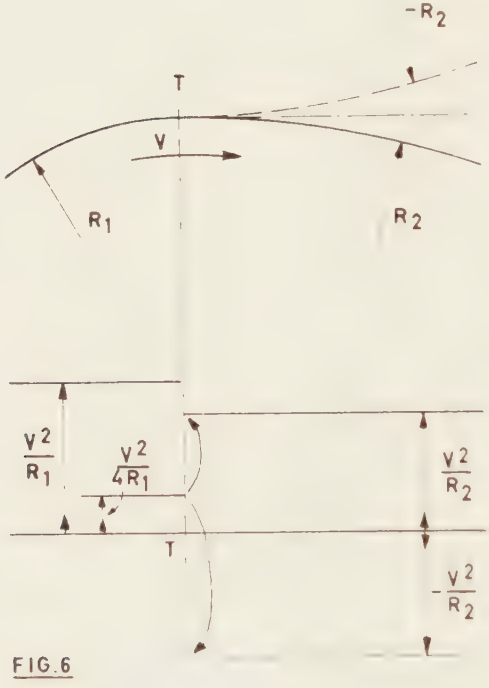


FIG.6

length of the section TD along which the thrust is damped, i.e. the maximum section still justifying the application of the notion « curve interrupted by a short straight section ». For, we shall ignore the fact that the thrust might tend to fluctuate during a certain period of time on either side of the zero point. A longer interruption would render the two branches of the curve independent of each other. In these circumstances, we obtain :

$$t = \frac{V^2}{4\,Rc} \tag{24}$$

and

$$l_M = Vt = \frac{V^2}{4\,Rc} \cdot V. \tag{25}$$

If a second curve begins at T', i.e. before the thrust due to the first curve is completely eliminated, the reduction in the thrust obtained at T' works out at :

$$\frac{V^2}{4\,R} \cdot \frac{l}{l_M} = \frac{cl}{V}. \tag{26}$$

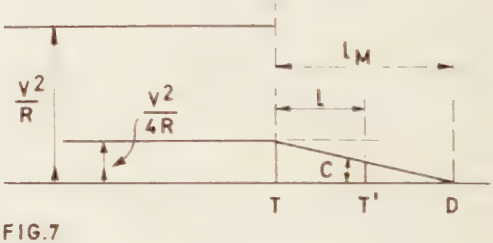


FIG.7

In all the preceding relations, the terms relating to the curve just passed must therefore be reduced, in absolute value, by $\frac{cl}{V}$ in order to take into account the presence of a short intermediate section of straight track.

It is now essential to determine the value of c which, to our knowledge, has not yet been determined experimentally. Logically, this value should be constant for a vehicle of a given type, but shall vary as between one type of vehicle and another; it is therefore necessary to try and obtain this value empirically.

An examination of the question in the light of present experience shows that a

value of **15** corresponds reasonably well to operating requirements and to the methods at present in use.

2. — **Curvatures in the same direction.**

This case is encountered at deviated lines of bifurcations and at points and crossings placed, separately or in groups, in curved track where the switches and crossings themselves do not have the same curvature as the through line, but are straight and tangent.

Consider a curve with two radii as shown in figures 1*a* and 2*a* and imagine it being cut apart at the tangential point *T*. Imagine, moreover, the two parts being removed from each other and the gap filled by a tangential section of straight track *TT'*, having the length *l*. We are then again confronted with the position shown in figure 7.

If we now revert to relations (7) and (18) and introduce into them the corrective term $\frac{cl}{V}$, we obtain :

$$\frac{V^2}{R_1} - \frac{V^2}{4\,R_2} + \frac{cl}{V} \leqslant 64\,h + \frac{3}{4}p_M \qquad (27)$$

$$\frac{V^2}{R_2} - \frac{V^2}{4\,R_1} + \frac{cl}{V} \geqslant 64\,h - \frac{3}{4}p_M. \qquad (28)$$

according to the direction of running.

In this general form, these relations are applicable to deviated lines of groups of points and crossings. The equations are of the third order in respect of *V*. To facilitate their solution in regard to this variable, the value of *V* appearing in the denominator of the corrective term should first be estimated, and the value of *V* obtained from the first two terms should be calculated. If necessary, this procedure should be repeated so as to obtain successive approximations.

If, in the two preceding formulas, *l* assumes the value l_M, it will be seen that the first of these formulas leads back to equation (8) whilst the second formula proves once more that the cant at the exit point of the curve must not exceed 0.09 m.

Where the through track of the points lies in a continuous curve, the preceding formulas can be applied provided that one sets $R_1 = R_2 = R$, which leads to the twin relation :

$$85\,h - p_M - \frac{4}{3}\frac{cl}{V} \leqslant \frac{V^2}{R} \leqslant 85\,h + p_M - \frac{4}{3}\frac{cl}{V}. \qquad (29)$$

In practice, however, conditions are such that there is little point in taking the first of these inequalities into consideration.

The corrective term $\frac{cl}{V}$ merits some further discussion. As the factor *c* marks the (constant) rate at which the thrust decreases at the exit from a curve, it will be seen that the corrective term is the greater the longer the straight section interposed between the curves. This appears to be quite normal, and it is found that, if *l* attains or exceeds the maximum value :

$$l_M = \frac{V^2}{4\,R_1 c} \cdot V \quad \text{or} \quad \frac{V^2}{4\,R_2 c} \cdot V$$

(where R_1 and R_2 are the radii of the arcs of the circle *just passed*), the two arcs must be regarded as being completely independent of each other. Moreover, the corrective term is the smaller the greater the speed *V*, due to the fact that, with *c* = constant, a higher speed *V* will result in a greater distance l_M over which the thrust is eliminated, and in a smaller loss of

thrust over a given section l. In the extreme case, if V is very great, the corrective term becomes imperceptible and, owing to their suspension, the bodies of the vehicle will hardly react to the discontinuity in the alignment, encountered by the wheels.

One might like to calculate separately the amount of the reduction in speed resulting from the interruption of a curve by a short section of straight track. If ΔV is the loss in speed, one obtains approximately :

$$\Delta V = -10 \frac{R}{V^2} \cdot l. \qquad (30)$$

In practice, the requisite reduction in speed is of the order of 3 to 10 km/h, and is, as already mentioned, the smaller (for a given radius) the greater the speed. Because of the rounding of the final figures, it is advisable to calculate the permissible speed direct from formula (29), and not to reduce, by an already rounded figure obtained from formula (5), the result obtained from formula (30).

3. — Curvatures in opposite directions (*S*-curves).

This case is of particular interest because of the crossovers in straight track. Let us therefore first of all assume that the cant is zero.

The introduction of the corrective term into equation (14) yields :

$$\frac{V^2}{R_1} + \frac{V^2}{4\,R_2} - \frac{cl}{V} \leqslant \frac{3}{4} p_M \quad \text{or} \quad 5.7. \qquad (31)$$

Relation (23), which applies to running in the opposite direction, yields a similar equation. In most cases, however, the radii are the same, i.e. $R_1 = R_2 = R$; hence :

$$\frac{V^2}{R} \leqslant \frac{3}{5} p_M + \frac{4\,cl}{5\,V} \quad \text{or} \quad 4.6 + \frac{12\,l}{V}. \qquad (32)$$

To calculate the connecting sections in cases where use is made of switches of given and known characteristics, this equation is, in general, solved for l in order to determine, from this value, the necessary distance between tracks :

$$l \geqslant \left(\frac{V^2}{R} - 4.6 \right) \frac{V}{12}. \qquad (33)$$

An *S*-curved layout is sometimes also encountered where the through line of crossing tracks is in a continuous curve.

E. SWITCHES

1. — General.

The theory developed above also permits the calculation of the permissible speed at switch-tips where the angle of switch forces the vehicle to change direction.

Consider (in fig. 8*a*) a switch with the straight stock rail represented by *DE* and the tongue, having the angle of switch α, by *PF*. The angle α is always sufficiently small to enable the sine and the tangent, without any significant error, to be substituted for the arc, and to enable the cosine to be taken as unity. Section *PF*, of the length a, is straight; it is followed by a section of curve *FG* with the radius r, which may or may not form part of the switch proper. It may also happen that the length a is equal to zero.

On this deviated track may be superimposed a straight line *AB* of length d, representing a vehicle reduced to its

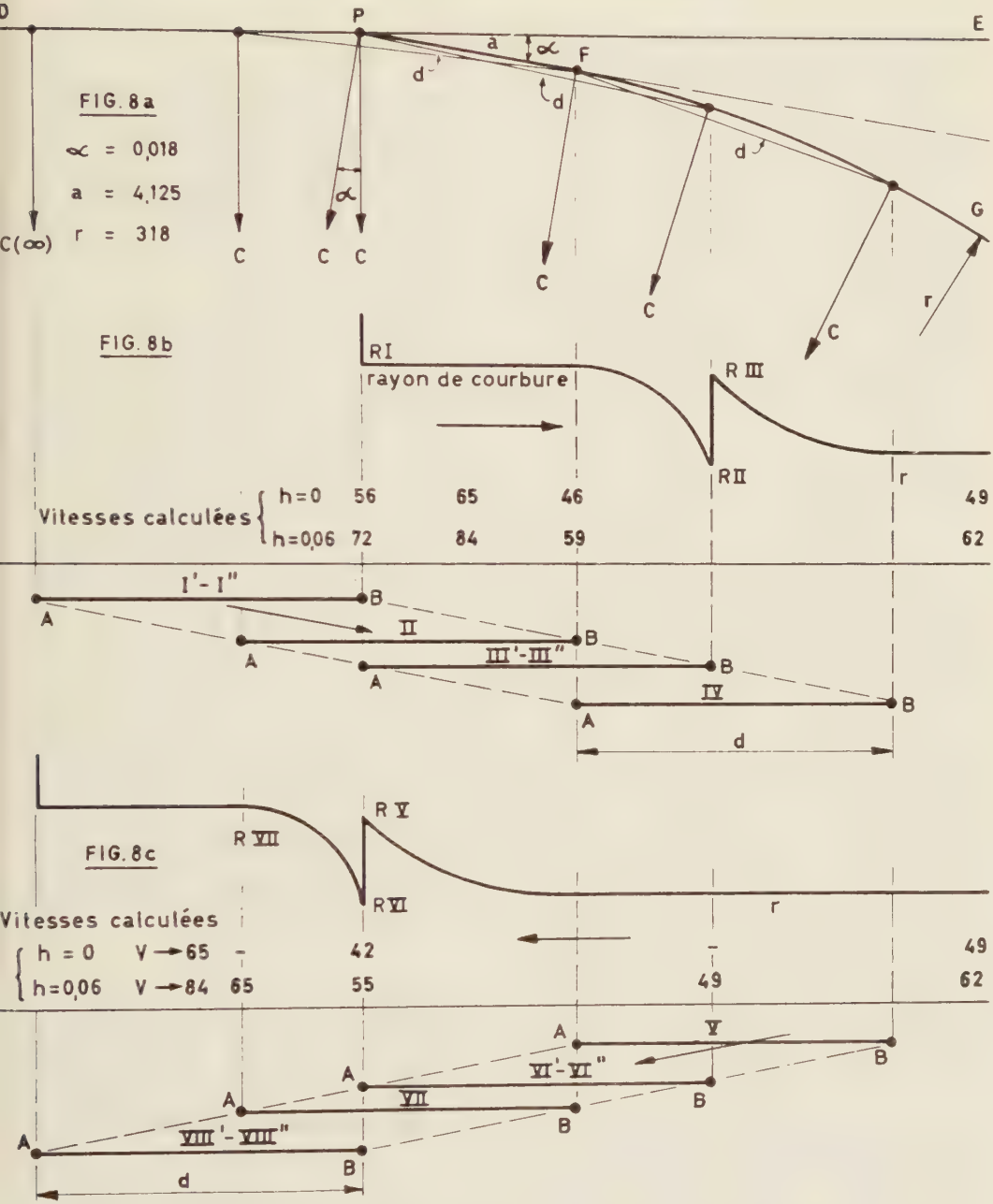


Fig. 8.

N.B. — Vitesses calculées = calculated speeds. — Rayon de courbure = radius of curvature.

centre line ($d > a$) and supported on the section of track concerned at its ends A and B, representing its axles or bogie pins.

When moving, this vehicle describes a succession of curves of small development and different radii; in any position, the momentary centre of rotation, C, is located at the intersection of the perpendiculars drawn through A and B in respect of the trajectories followed by these moving points. During this movement, several phases may be distinguished, separated from each other by characteristic positions occupied by points A and B on their itinerary.

2. — **Movement from D to G.**

The movement of AB can be followed on the scale drawn at the bottom of figure 8 *b*, and the heavy line at the top of that illustration indicates the value of the radii of the curves negotiated by the vehicle, related in each case to the location of point B.

Position I′ : Point B is just ahead of point P; the two perpendiculars intersect in infinity, and the vehicle is in a straight alignment.

Position I″ : Point B has just passed point P; the perpendicular at the latter point is suddenly placed perpendicular to PF; the angle formed by the two perpendiculars amounts to α and their point of intersection has the distance :

$$R_I = \frac{d}{\alpha}. \qquad (34)$$

This is the radius governing the movement of the vehicle during the first phase. The curve has been entered without a transition curve, and the permissible speed at this point is given by formula (8) :

$$V^2 \leqslant (64\,h + 5.7)\,\frac{d}{\alpha}. \qquad (35)$$

Position II : Axle B has arrived at F; the leading axle of the vehicle leaves the curve of radius R_I and enters, without passing through a transition curve, the curve of radius r. We can now use formula (7) which is normally applicable to this case, and obtain :

$$V^2 \leqslant (64\,h + 5.7)\,\frac{r}{1 - \frac{\alpha r}{4d}}. \qquad (36)$$

Position III′ : The rear axle A is arriving at point P without, however, having quite reached it; the angle formed by the two perpendiculars, previously equal to α, has increased by the value $\frac{d-a}{r}$ and the radius R has gradually assumed the value :

$$R_{II} = \frac{d}{\alpha + \frac{d-a}{r}}. \qquad (37)$$

Position III″ : Axle A has passed point P, and the perpendicular at this point is inclined at the angle α. The angle is now reduced to the value $\frac{d}{r} - \frac{a}{r}$ so that the radius abruptly changes to :

$$R_{III} = \frac{d}{\frac{d}{r} - \frac{a}{r}}. \qquad (38)$$

The sudden transition from the small radius R_{II} to the large radius R_{III} brings formula (18) into play, but as this condition is always realized in practice, there is no point in insisting on it.

Position IV : Axle A reaches point F so that the vehicle has now fully entered the curve of radius r; it can be assumed that

the transition from III to IV is not governed by the curve entry conditions of formula (8), since the leading axle is already in the curve while the second axle occupies a favourable position, slightly inclined towards the curve; in this case, formula (5) can be applied directly, viz :

$$V^2 \leqslant (85\,h + 7.6)\,r$$

The heavy line in figure 8 *b* is drawn to scale and has been obtained by applying the foregoing to an actual turnout. The figures shown against it indicate the speed calculated with the aid of the formulas given above. The numerical data were :

$\alpha = 0.018$; $a = 4.125$ m; $r = 318$ m.

For *d*, the figure that appears to be most suitable has been adopted, viz. **10.**

3. — **Movement from *G* to *D*.**

If the vehicle moves in the opposite direction, it will be guided by axle *A*. The curve radii of the trajectory of the vehicle remain the same, though the diagram in figure 8 *c* differs from the preceding one because the calculated values of the radii are plotted for the successive positions of point *A* (instead of *B*), and the effects of the abrupt changes of radius are not the same.

Position V : Emergence from the curve of radius *r*; the speed must not exceed the value given by formulas (5) or (19).

Position VI′ : Before point *P* is reached, the perpendiculars form the angle $\frac{d-a}{r}$, and the radius is :

$$R_V \quad \frac{d}{\frac{d-a}{r}} \quad R_{III}.$$

Position VI″ : beyond point *P*, the angle is increased by α and the radius becomes :

$$R_{VI} \quad \frac{d}{\frac{d-a}{r} + \alpha} \quad R_{II}.$$

As the movement is from the larger radius R_V to the smaller radius R_{VI}, one obtains :

$$V^2 \leqslant (64\,h + 5.7)\,\frac{r}{\frac{3}{4} - \frac{3a}{4d} + \frac{\alpha r}{d}} \qquad (39)$$

Position VII : The vehicle has arrived, though without passing through a transition curve (parabolic or similar), in the curve of radius :

$$R_{VII} = \frac{d}{\alpha} = R_I.$$

The movement is from the smaller to the larger radius, giving rise to virtually no speed limitation.

Position VIII′ : The rear axle *B* has not yet passed point *P*, and the curve described still has the radius R_{VII}.

Position VIII″ : Axle *B* has passed point *P* and the two perpendiculars to the trajectory are parallel; the vehicle has emerged from the curve, and the speed is limited to the value obtained from formulas (5) or (19).

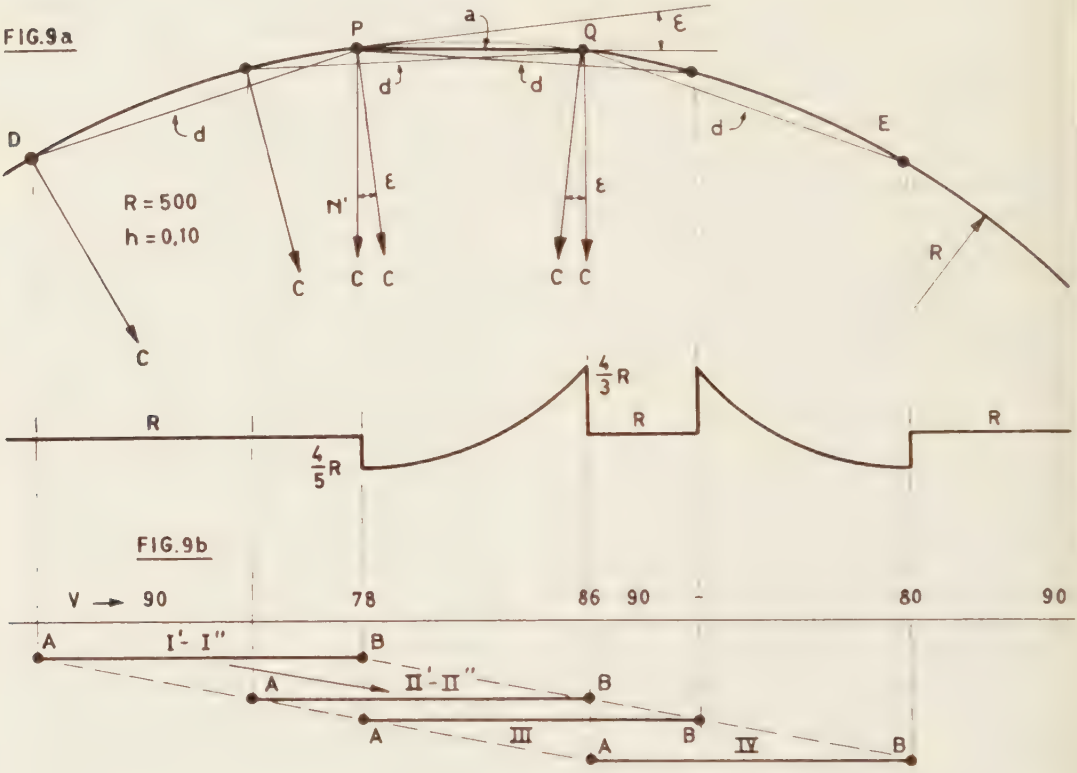
The figures inscribed in figure 8 *c* relate to the same actual turnout as the one on which the preceding figure 8 *b* was based.

4. — **Discussion.**

The turnout which serves as an example in the preceding considerations was ori-

ginally designed for an authorized speed of 50 km/h without superelevation, and 60 km/h with an overall superelevation of 60 mm. It will be seen that the agreement is not perfect, especially if the point is negociated from heel to tip. There was admittedly, at that time, no precise rule for the angle of switch, and turnout curves could exceptionally be regarded as being provided with transition curves. When entering from the tip, the critical moment is that at which the switch curve is reached. When entering from the heel, the combined effect of the curve and of the deviation at the tip of the tongue is even more detrimental. This explains why the shock on leaving the switch is generally greater than that on entering it.

It is found that, on the whole, the value $d = 10$ can be regarded as satisfactory. This is mainly apparent from other comparisons with current practice which yield results that are sometimes in agreement and sometimes, as in the concrete example just discussed, in slight disagreement.



F. TRACK ALIGNMENT FOLLOWING THE CHORD

There is a method of arranging points and crossings in curves in such a way that

the main lines of switches, acute and obtuse crossings are placed in a through track forming a continuous circular curve, but follow the chord of that curve without themselves being curved. Let us see the effect which this arrangement may have on the speed.

Let (in fig. 9 *a*) $PQ = a$ be the length of one element of such a layout, located in a continuous curve DE with the radius R.

Position I′ : the vehicle, of length d, is in the position AB, with axle B just approaching P; the curve radius is R.

Position I″ : If B has just passed point P, the perpendicular at that point will be the line PN' normal to PQ; the angle ε between the radius and the perpendicular at P amounts to $\frac{a}{2R}$, whilst the angle between the radius through A and the perpendicular at P will be $\frac{d}{R} + \frac{a}{2R}$, hence :

$$R_I = \frac{d}{\frac{d}{R} + \frac{a}{2R}} = \frac{R}{1 + \frac{a}{2d}}, \qquad (40)$$

a value which is smaller than R (fig. 9 *b*).

We then obtain with the aid of formula (7) :

$$V^2 \leqslant (85h + 7.6) \frac{R}{1 + \frac{2a}{3d}}. \qquad (41)$$

Position II′ : While B negotiates the straight section PQ, the radius changes progressively. At Q, the angle formed by the perpendiculars assumes the value :

$$\frac{d - a}{R} + \varepsilon = \frac{d - \frac{a}{2}}{R},$$

so that the radius becomes :

$$R_{II} = \frac{R}{1 - \frac{a}{2d}}. \qquad (42)$$

Position II″ : As the front axle has passed point Q, the whole vehicle is again moving on the curve of radius R as if the anomaly of the section PQ had not existed. Taking this abrupt change in radius into account, we obtain the speed permissible at this point :

$$V^2 \leqslant (85h + 7.6) \frac{R}{1 + \frac{a}{6d}}. \qquad (43)$$

Positions III and IV : the phenomena here encountered are inverse to those described above; they are more favourable from the point of view of permissible speed and shall not be further discussed here.

Of the two formulas (41) and (43), it is the former which imposes the more restrictive speed limit.

In general, it is permissible to assume $a \cong \frac{d}{2}$. hence :

$$V^2 \leqslant \frac{3}{4}(85h + 7.6) R,$$

which leads us back to formula (8) for entering a curve without transition curves, and calls for a speed reduction by 13%. It is of interest to note that, when the chord layout discussed above was introduced, and before the theory outlined above had been evolved, a speed restriction of 10% was imposed intuitively.

For radii greater than 800 m, the length of section a may become approximately equal to d. In this case, one obtains :

$$V^2 \leqslant \frac{3}{5}(85h + 7.6) R \qquad (44)$$

and the speed reduction should be 23% of the speed which would be normally authorized in the absence of the points or crossings.

Inversely, if it is desired to calculate the cant required for a given radius and a given speed, the two last-named formulas yield :

$$h \quad \frac{4}{3} \quad 0.0118 \frac{V^2}{R} - 0.09 \qquad (45)$$

and $$h = \frac{5}{3} \times 0.0118 \frac{V^2}{R} - 0.09. \qquad (46)$$

It will therefore, in certain cases, be sufficient to increase slightly the cant in order to avoid or mitigate a speed restriction which is regarded as unacceptable.

G. SUMMARY

The preceding essay represents an extension of the conventional classic theory governing the calculation of the speed as a function of curve radius and superelevation, taking into account a possible cant deficiency. This theory can be summed up in the relation recalled at the beginning of this article :

$$\frac{V^2}{R} \leqslant 85\,h + p_M \qquad (5)$$

which we have used with the value $p_M = 7.6$; this value, however, may be altered, for instance into 8.5, or 10 or even 12.

The present study is mainly concerned with those cases where transition curves are absent, i.e., where the curvature changes are abrupt, and a further extension of the method permits the solution, based on the same principles, of the problems associated with angular junctions.

The junction between circular curves turning in the same direction but having different radii represents a case which is of little interest in practice but forms the basis for all further developments of the theory. It gives rise to two inequalities, viz.

$$\frac{V^2}{R_1} - \frac{V^2}{4\,R_2} \leqslant 64\,h + 5.7 \qquad (7)$$

for running from the section with radius R_2 to that with radius R_1, and

$$\frac{V^2}{R_2} \quad \frac{V^2}{4\,R_1} \quad 64\,h \quad 5.7 \qquad (18)$$

for running from the section with radius R_1 to that with radius R_2 (R_2 is always greater than R_1).

But there are two special cases where the application of these formulas is of particular importance; they are : the entry into a curve :

$$\frac{V^2}{R} \leqslant 64\,h + 5.7, \qquad (8)$$

resulting in a speed reduction of 13% of the normal speed governed by formula (5), and the exit from a curve :

$$\frac{V^2}{R} \quad 4 \times (-64\,h + 5.7). \qquad (19)$$

In these cases, the cant is often zero.

The method permits the calculation of the permissible speed if a series of circular arcs curving in the same direction are separated by short straight sections as in a complex of points and crossings :

$$\frac{V^2}{R_1} - \frac{V^2}{4\,R_2} \leqslant 64\,h + 5.7 - \frac{15\,l}{V} \qquad (27)$$

and

$$\frac{V^2}{R_2} - \frac{V^2}{4\,R_1} \geqslant 64\,h - 5.7 - \frac{15\,l}{V} \qquad (28)$$

according to the direction of running.

If the radii are equal, one obtains :

$$\frac{V^2}{R} \leqslant 85\,h + 7.6 - \frac{20\,l}{V}. \qquad (24)$$

The case of *S*-curves can be deduced from these formulas if the negative sign of the curve just left behind is converted into a positive sign. In most cases, there is no cant, and one obtains :

$$\frac{V^2}{R_1} + \frac{V^2}{4\,R_2} \leqslant 5.7 \qquad (14)$$

or

$$\frac{V^2}{R_2} + \frac{V^2}{4\,R_1} \leqslant 5.7 \qquad (23)$$

and if the radii are equal :

$$\frac{V^2}{R} \leqslant 4.6. \qquad (15)$$

If the two arcs curving in opposite directions are separated by a short section of straight alignment, the relevant formula is :

$$\frac{V^2}{R_1} + \frac{V^2}{4\,R_2} \quad \text{or} \quad \frac{V^2}{R_2} + \frac{V^2}{4\,R_1} \leqslant 5.7 + \frac{15\,l}{V} \qquad (31)$$

and if, as with crossovers, the radii are equal :

$$\frac{V^2}{R} \leqslant 4.6 + \frac{12\,l}{V}. \qquad (32)$$

From a speed calculation point of view, switches represent complicated layouts and call, in each case, for a thorough study; suffice to recall here the effect on the speed of the angle of deviation (having the value α or tg α) :

without cant :

$$V^2 \leqslant \frac{57}{\alpha} \qquad (35)$$

and with a cant of 60 mm :

$$V^2 \leqslant \frac{95}{\alpha} \qquad (35)$$

Finally, in the exceptional case where an otherwise continuous circular curve contains a « flat » section of about 6 m length, the speed must be reduced by 13% of the speed normally permitted as if it was an entry into a curve without transition curves (formula (8)). If the « flat » section is as long as 10 or 12 m, the speed must be reduced by 23%.

[656 .25 (42)]

Further progress with the use of programme machines for the automatic operation of points,

Underground Railways of London,

by R. Dell, O.B.E., M.I.E.E., M.I.MECH.E., M.I.R.S.E.,

Signal Engineer, London Transport Executive.

The first installation of programme machines for the automatic setting of junctions was brought into operation in 1958, and was described in the Bulletin of the I.R.C.A. for February 1959.

During 1960, programme machines were installed on a branch line between Earls Court and Putney Bridge, and signal boxes which previously existed at Parsons Green and Putney Bridge on that line, have been abolished.

Supervision of the programme machine

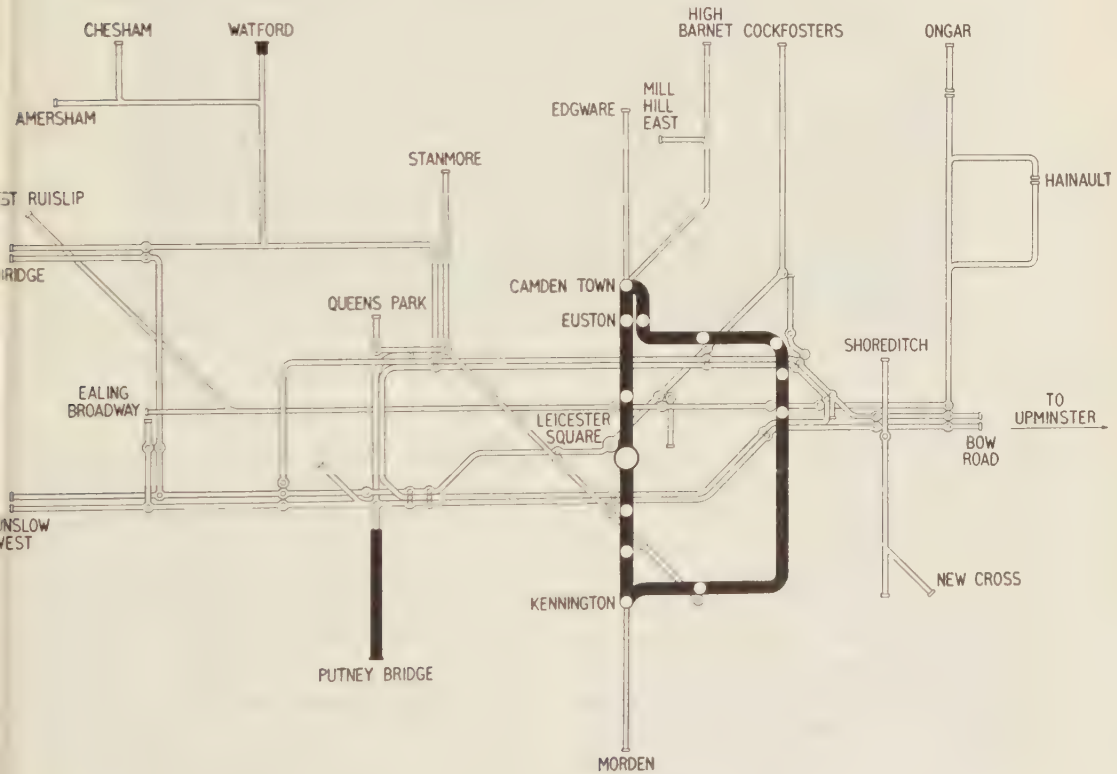


Fig. 1.

working on this section of the line is carried out from a temporary office situated at Earls Court, but it is planned to provide a permanent supervision room at Earls Court, which can include the supervision of further installations of programme machines on the District Line.

The map of the Underground Railway (fig. 1), shows the sections of London Underground Railways where the signalling of junction working is now operated by programme machines.

The programme machine carries the particulars for each train on the timetable for the whole day. The programme itself comprises a roll of plastic film 20 cm wide, and the information for each train is in the form of a row of punched holes across the film. The programme roll is mounted on two rollers and is driven by a small electric motor through magnetic clutches, so that the roll can be moved in either direction.

The holes punched in the programme roll are read by the machines by means

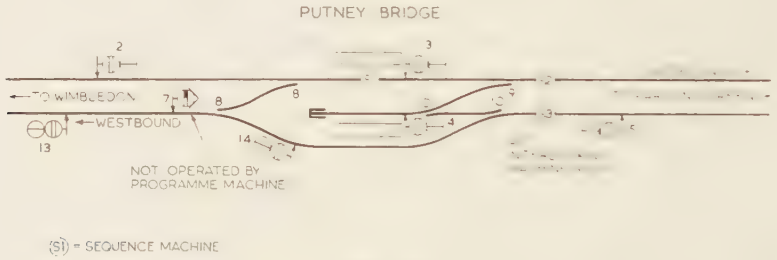


Fig. 2.

Putney Bridge.

Figure 2 shows the track layout at Putney Bridge, and this presents no special problems for programme machine working. As will be seen from the diagram, there are through tracks through the station, and an additional platform road through which a portion of the train service is reversed. Crossover No. 8 is not controlled by the programme machine, as this crossover is only used very occasionally for emergency working.

The programme machines used are identical in design to those described in the article in the Bulletin for February 1959, but an important change has been made in the identification of the train on the programme roll.

of a series of feelers which actuate contacts. These feelers are pressed on the surface of the roll and where the feeler enters a hole in the roll, the contact is closed. Where there is no hole in the roll, contacts are kept open.

In the present installation, in addition to the information with regard to the destination of the train, the route it has to take, the actual number of the train is punched in decimal binary numerals on the programme roll and is read by the programme machine. With this arrangement, an illuminated number showing the number of the train being signalled is shown in the supervision room.

Three sequence programme machines

are required at Putney Bridge, No. 1 to receive trains from Wimbledon, No. 2 to determine the order of trains from Wimbledon or from the bay road platform, and No. 3 determines the working on the westbound track, either signalling the trains to Wimbledon or into the reversing platform road.

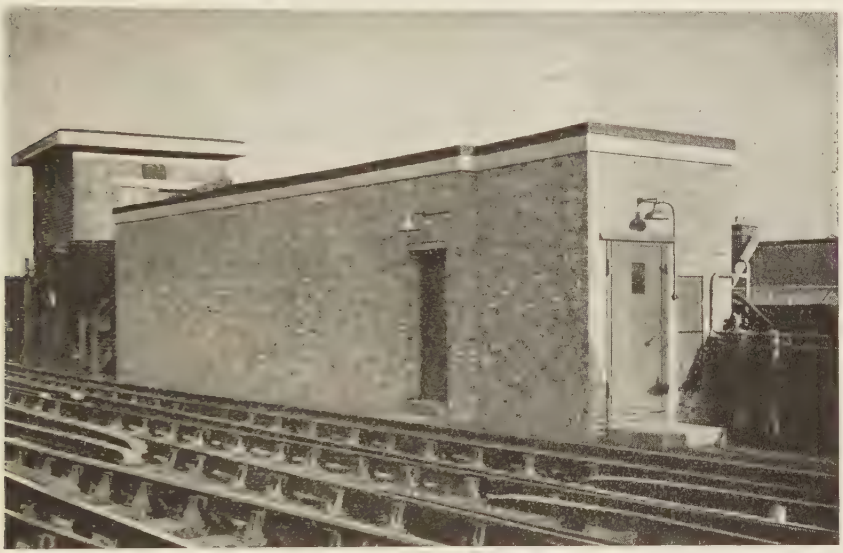


Fig. 3. — Putney Bridge. Interlocking machine room.

One time-operated programme machine serves all three sequence machines at this installation.

The programme machines are housed in the same room as the interlocking machine, which is used for the initiation of the safety circuits.

Figure 3 shows a view of the interlocking machine room at Putney Bridge. The higher building to the left is the signal box, now disused.

Parsons Green.

The track layout at Parsons Green is shown diagrammatically in figure 4, and comprises two through passenger lines with sidings on both sides of the tracks at both ends of the station. These sidings are used for stabling trains at nighttime and also for stabling trains or parts of trains during the middle of the day when the service is less busy. The whole of the setting of the routes at Parsons Green is arranged to be carried out automatically by programme machines for bringing the trains out of the sidings into service, which frequently includes marshalling of the trains, signalling the trains into the sidings after the busy service, signalling the trains out of the sidings again in the afternoon, and finally signalling them in for the night. All the

movements of trains into or out of the sidings is arranged by the programme to fit in with the through passenger trains on the main line, which are also signalled by programme machine.

The complete working of the service during the day is in accordance with timetable, but it is necessary for some flexibility to be provided in deciding which siding a particular train shall use on any given day, and provision has been made for this in the equipment.

Two time-operated programme machines are provided to co-operate with the four sequence machines.

The method by which the programme machines work is that the programme machine reads the information for each train from the programme roll, including the train number, and if the train is shown to terminate at Parsons Green, the main line programme machine then offers the train by number to the siding programme machine, which, if the numbers coincide, accepts the train and after reference to the siding allocation panel, routes the train into the siding.

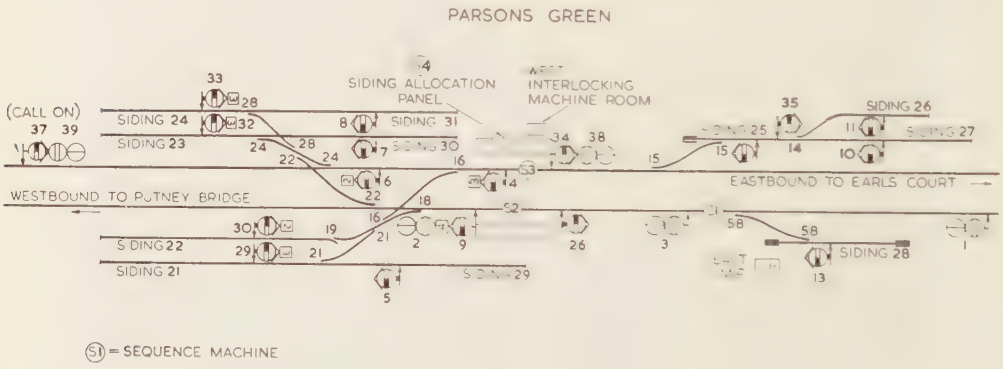


Fig. 4.

Programme machines.

A total of four sequence programme machines is used for the control of the Parsons Green service. Three of these machines control movements on the main line and one machine — No. 4 — is reserved for movements into or out of the sidings only.

Machines Nos. 1 and 2 deal with trains through the westbound road, machine No. 3 deals with trains through the east bound road, and machine No. 4 deals with all movements to or from sidings.

If, however, the train to be signalled is a through passenger train, the main line programme machines signal it straight through and machine No. 4 is not affected.

Interlocking machine.

An interlocking machine (fig. 5) carrying 36 shafts, is provided at Parsons Green, and this, together with the standard track circuit relays, comprises the

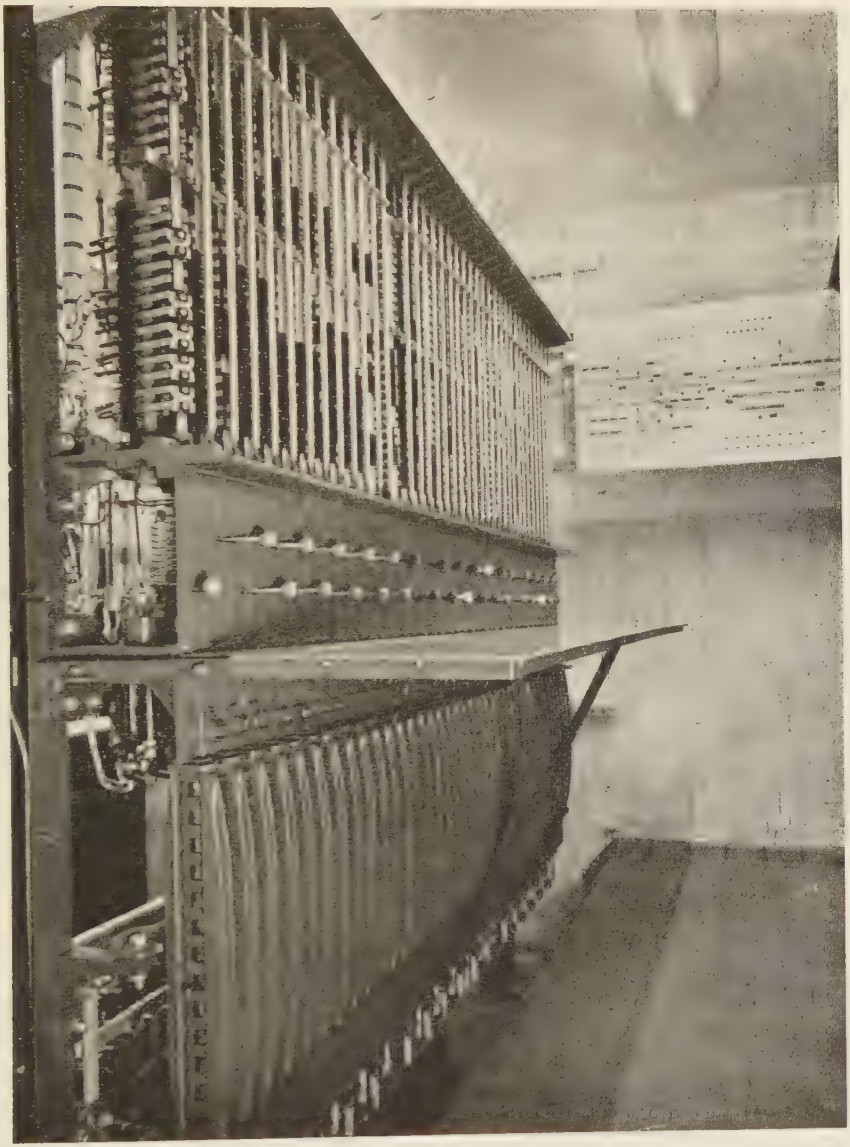


Fig. 5. — Parsons Green West. Interlocking machine.

safety signalling installation. This installation provides the fullest protection for each train movement by track circuit, and in addition, the shafts are not freed until a train has been proved to have completed the route. This additional safeguard is provided by the use of a 10 Kc rail circuit which is situated a

full train length beyond any points included in a route.

Siding allocation panel.

To provide a measure of flexibility in the working, a siding allocation panel has been provided at Parsons Green, situated in the yardmaster's office, and electrically connected to the programme machine circuits. This siding allocation panel is shown in figure 6. It comprises a series of rotary switches operated by knobs on the front of the panel. These switches are arranged in groups of three, and form a 3-digit train number. Figure 7 shows a close-up view of one set of switches.

On the panel, the sets of rotary switches are arranged in lines corresponding with the sidings which are used for stabling trains. Some of the sidings are used much more than others, and the sidings with the greatest use are given a larger number of switches. It will be noted that there are two additional groups for sidings 21 and 23 at the bottom righthand corner.

To use the panel, the yardmaster sets the dials to show the numbers of the trains required to come out from or enter the particular siding in their order of procedure, reading from the left.

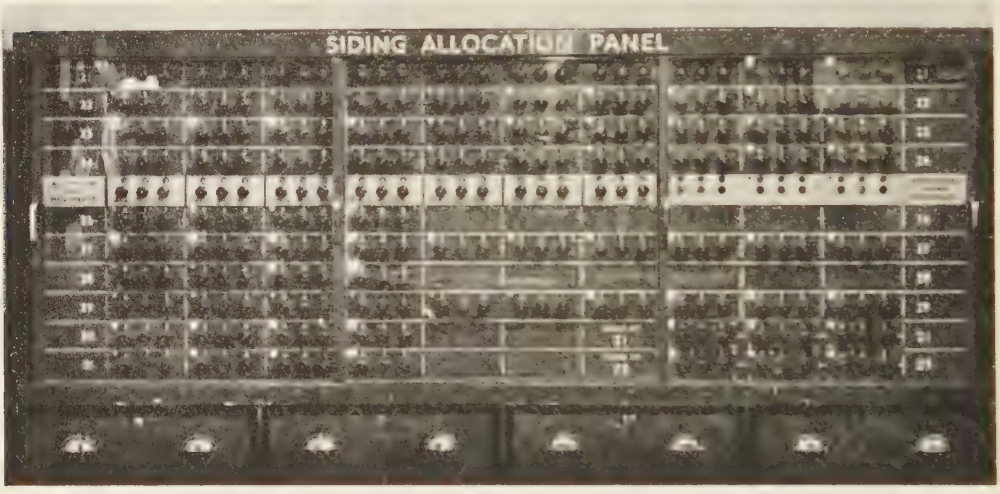


Fig. 6.

Once the siding allocation panel has been set there is no need to alter it, except when some change in the stabling of trains is required, and the panel could be set on Monday and left without any further setting until Friday if a fixed pattern of stabling is desired. If, on the other hand, the yardmaster requires to alter the position in which trains are stabled, he changes the setting of the dials to show the fresh train numbers required.

A lamp is provided on each of the

switch groups on the siding allocation panel, and this lamp being alight shows that that particular train movement has not yet been carried out. As each train movement is made, so the appropriate lamp on the siding allocation panel is extinguished.

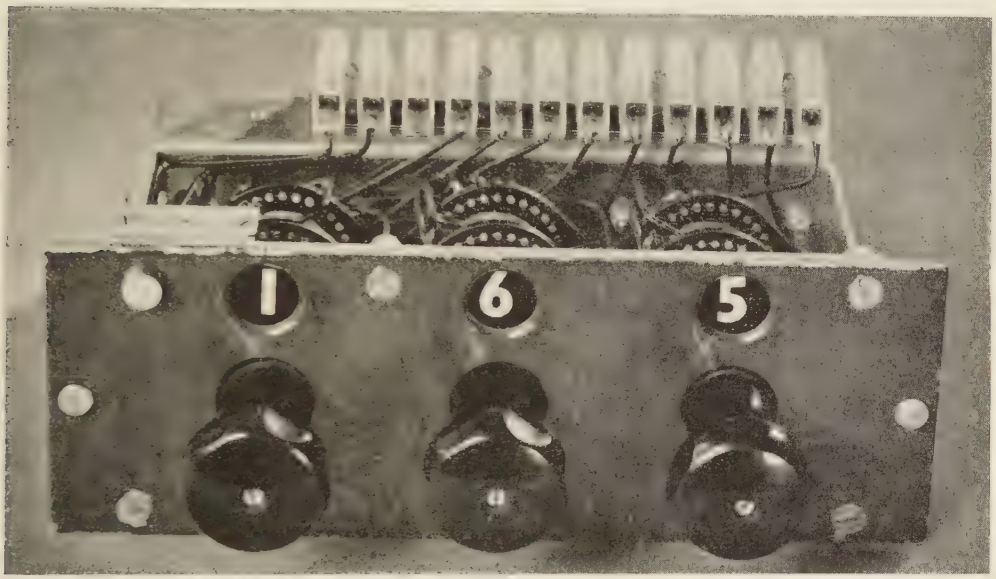


Fig. 7. — Siding allocation panel. Switch unit.

Figure 8 shows a schematic diagram of the connections between programme machine No. 4 and the siding allocation panel.

To consider one train movement, we will consider that train No. 36 is the first train in the morning, and the siding allocation panel has been set to show train No. 36 to originate from siding No. 23. The time for the train to be brought out of the siding will be indicated by the time-operated programme machine and siding programme machine No. 4 coinciding to show train 36. Programme machine No. 4 will then, by means of a scanning circuit, offer the number 36 to the siding allocation panel siding by siding, and when the number set on the dial of the panel also shows train 36, a coincidence circuit is completed and stops the scanning circuit on that siding line on the allocation panel. The position in which the scanning relays have stopped then provides the information of the route from the siding which has to be set.

The completion of the route, that is the information as to which platform the train is to be brought into, is given from the programme roll of machine No. 4, and so by a combination of the two sets of information, the shafts of the interlocking machines are operated to set the

points and clear the shunt signal for the train to run into the platform. After the train has picked up passengers, the main line programme machine then, at the correct time as determined by coincidence with the time-operated machine, signals the train away. As soon as the train has left the siding, the relays associated with the siding allocation panel, step along that siding by one switch, thus eliminating the train No. 36 and at the next excursion of the scanning relays, it is the second switch on the line of 23 siding which will be interrogated.

Taking a train proceeding in the opposite direction, that is from service into a siding, the main line programme machines Nos. 1 and 2 on the westbound road, for example, will show a train terminating at Parsons Green. The electrical circuits then check that the train describer is in agreement and this being so, the main line machine No. 2 offers the train by train number to the siding machine No. 4 and if the siding machine is seeing the same train number, it then offers this train number to the siding allocation panel. The scanning relays proceed to step along the electrical circuits of the panel until a switch is found which has been set to the train number offered. The scanning circuits then stop at the siding containing switches which have been set to the particular train number. As this particular train movement can be assumed to originate from the westbound track, and cross over the eastbound track, the circuits of the pro-

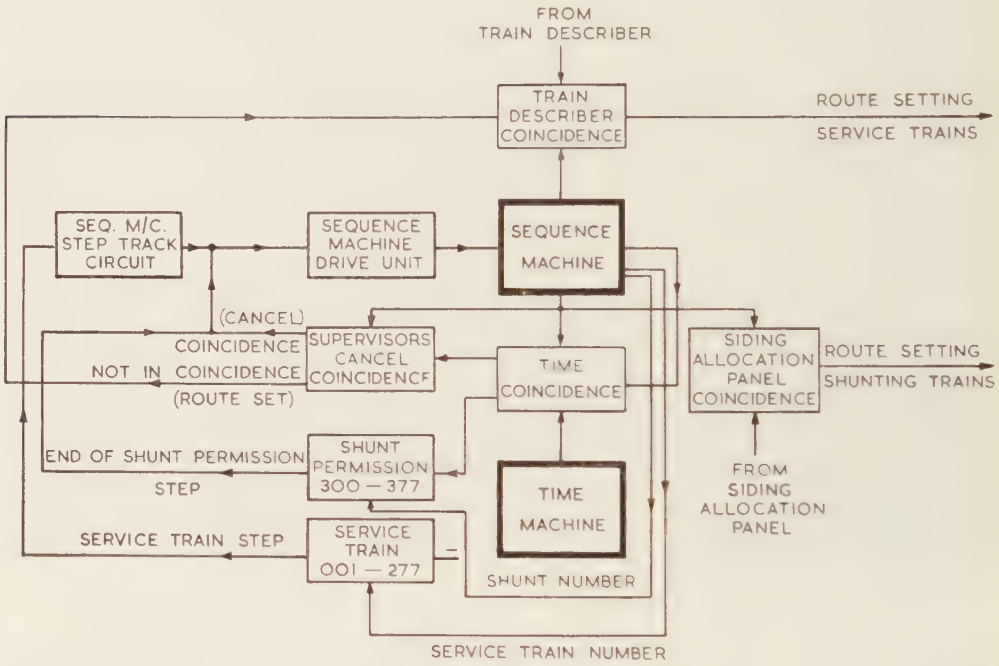


Fig. 8.

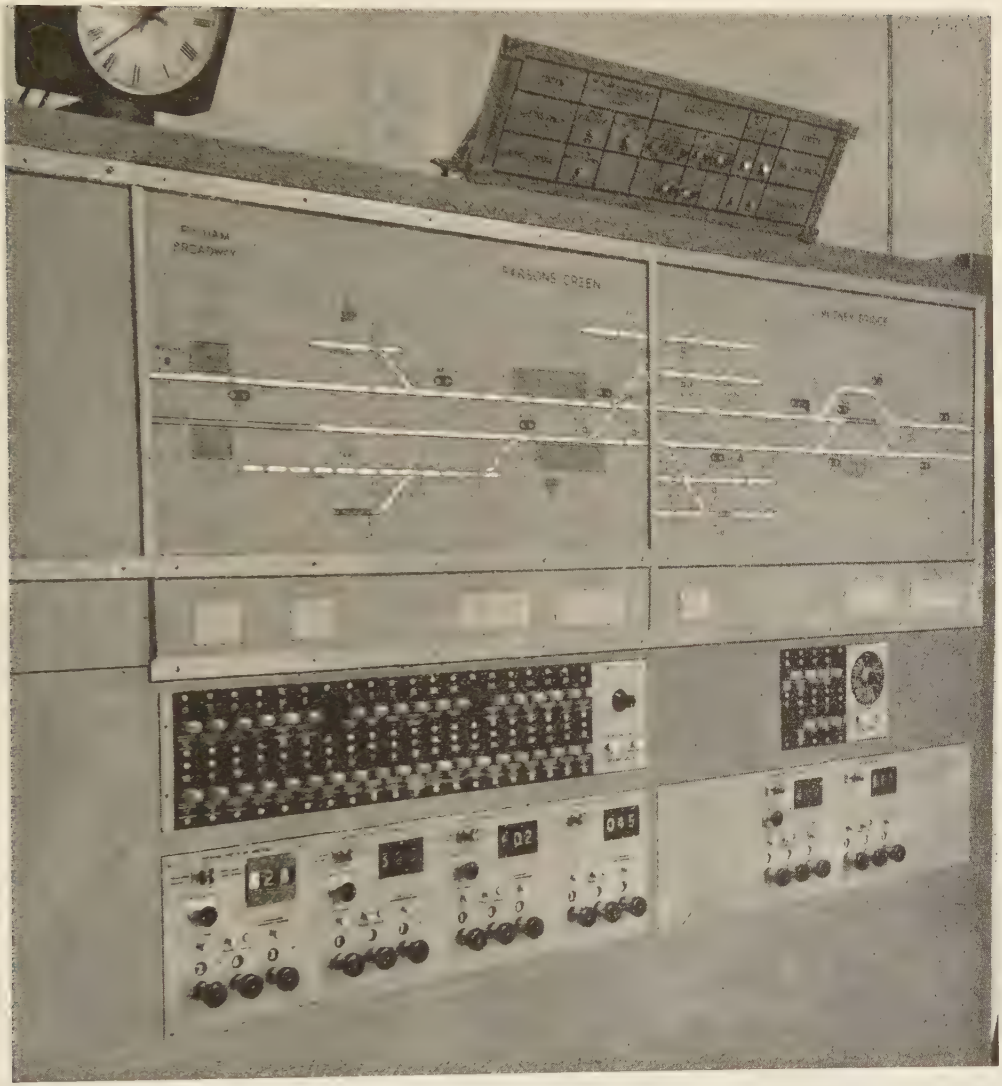


Fig. 9. — Earls Court. Panel in the supervision room.

gramme machine are arranged to ensure agreement with the programme machine controlling trains on the eastbound line, so that the move is only signalled in between service trains. This effect is achieved by additional punchings on the programme roll, providing for shunt paths between the service trains. These shunt paths are automatically cancelled two minutes before a through train is due.

Provision is also made on the siding

allocation panel for additional shunt movements which could not be pre-programmed, and these are carried out on the switches arranged on the light coloured strip that can be seen on the photograph of the siding allocation panel, below siding 24.

On the programme machine rolls, when a gap occurs between successive trains in the normal service, a shunting path is allowed for by additional punching. These shunt paths are identified by numbers in the 300 group and are shown on a special timetable. If it is required, therefore, to make a special unpremeditated train movement, it is necessary to pick a shunt path at the time that the movement is wanted, and by setting one of the dial switches to the shunt path number, and to the siding number, this indicates the destination of the train movement required, and it is then only necessary to press a plunger at the signal in the siding from which it is required to move the train for the route between the two sidings to be set, and the signal is lowered.

Programme machine supervision room.

At Earls Court, a programme machine supervision room has been provided for supervision of the programme machine working of the installation at Parsons Green and Putney Bridge. Figure 9 shows the panel in the supervision room. Below the illuminated diagram, are a strip of panels on which the train descriptions are shown, and below this a set of push buttons which can be used for hand-working in event of emergency, and at the bottom of the panel are the groups of switches for controlling the programme machines : four for Parsons Green and two for Putney Bridge.

The illuminated number at the right-hand corner of each switch panel shows the train number of the train being dealt with, and to the left of this is the switch which arranges for the circuits to be worked from programme machine or push button or first-come, first-served.

The three knobs at the bottom of each group are used for cancelling trains. In this installation, cancelling of trains is done by setting the train number on rotary switches by means of these knobs. It is only necessary to set the train number of the train to be cancelled, and when that number appears on the programme roll, the machine automatically steps twice, passing over the cancelled train.

625 .234]

Hot air heating of passenger coaches,

by S. Doppler, Wien.

(*Elektrotechnik und Maschinenbau*, No. 18, 15th September 1960.)

The heating of passenger coaches naturally began with steam heating because on lines worked with steam locomotives, a sufficient quantity of steam was usually available. The heaters were fitted in the compartments and had a sufficient accumulative heat capacity for the compartments to remain relatively warm even when the driver had momentarily to restrict the supply of steam for heating.

But railway service is very difficult and exacting for a heating system and steam heating, in spite of the long years of experience over which modern heating arrangements could be studied, still involves a great deal of maintenance and is likely to give trouble when the temperature is very low.

With the introduction of electric traction, it became necessary to adapt electric heating for coaches, because for different reasons there could be no question of fitting a heating boiler on the electric locomotive, and the use of a wagon fitted with a boiler leads to too many complications.

By analogy with steam heating, the electric heating of the trains was first done as a rule with radiators in the compartments. But although this method of heating had a whole series of drawbacks from the point of view of heating technique, it was not this which led to the adoption of another method. The builders of coaches for international services were necessarily led to go more thoroughly into the whole question of heating the coaches. Unfortunately, the heating voltage is not standardised for the various Railway Administrations, and there are already at the present time five different approved voltages, standardised by the International Railway Union (UIC). On lines, where the traction supply is 3 kV D.C., the heating equipment must naturally be designed for the same voltage. In countries, where the voltage in the contact wire is 1.5 kV D.C., a heating voltage of the same value was also adopted. On lines, where the contact line is supplied with 15 kV 16 2/3 cycles A.C., for example the Austrian lines, an A.C. heating voltage of 1 kV, 16 2/3 cycles was adopted. Since a series of lines has been put into service with 50 cycles industrial current as well as the above, A.C. heating voltages of 1.5 kV, 50 cycles and 1 kV 50 cycles have been added.

These different heating voltages are found in Europe in a relatively concentrated area which can be travelled across in one day by train, in which there are also moreover steam lines. It was therefore necessary to design a heating system for the international coaches which could be used with all these different heating voltages as well as with steam.

Naturally, it is possible to have both electric and steam radiators in each compartment, and to group the former by means of an automatic or manual switching device fitted with some safety device as a protection against mistakes in connection, so that they always function correctly no matter what the heating voltage. This solution has been successfully used, after some initial difficulties by certain Administrations, but involves a whole series of drawbacks. These are due essentially to the weight and complication of the assembly, as well as difficulties in regulating, and to the fact that the high voltage of 3 000 V must be brought into each compartment with D.C. For this reason most of the Administrations are looking for some more satisfactory solution, at least in the case of coaches in international service.

The German Federal Railways have studied a hot water heating system, including a heat exchanger which can be supplied both by steam and electricity. In this exchanger, the water is raised to a maximum temperature of 90° C and circulated by natural circulation through the compartment radiators. This method of heating has undoubtedly many advantages over the old steam heating methods and heating by means of electric radiators. Its drawback is the great weight of such an installation. The water it contains alone weighs some 400 kg and the consumption of power needed to raise it to 90° C is about 42 kWh. Allowance must therefore be made for it to take a long time to warm up. In addition, to protect the installation against frost, antifreeze must be added to the water, and this addition must be checked and topped up, which involves additional maintenance costs. Other devices are also needed to assure the renewal of the air in the compartments. In spite of these drawbacks, a great many coaches have already been fitted with this system of heating, because it is better than heating by radiators in the compartments.

Most railway Administrations, in particular the Austrian Federal Railways, have adopted a hot air heating system for heating the coaches in international service. This system also includes a central heat exchanger which can be supplied either by steam or electric power. Fresh air is used as the heating medium and drawn in by means of fans through shutters at window level or on the roof. These shutters also prevent rain getting in. Behind them are the filter boxes which remove dust and soot from the air that is drawn in. The purified air is heated in the heat exchanger and taken into the compartments through pipes. The hot air comes out under the seats, as well as in the corridor and toilets. Part of the hot air can also be used to heat the water in the toilets and to protect the water tanks from frost unless they are fitted with special radiators for this purpose.

Coaches equipped with hot air heating usually have some device to make it possible to draw in some of the air from inside the coach itself. This arrangement should, however, only be used when running through tunnels full of smoke or when it is exceptionally cold and the heating capacity is insufficient to keep the coach pleasantly warm in the normal way.

The amount of fresh air taken into a coach heated by means of warm air is calculated in such a way that it just barely fulfils the requirements in the case of a fully loaded coach. It amounts to 1 200 to 1 400 m^3/h related to an average inside temperature of + 20° C, in other words, if there are 60 to 70 passengers in the coach, each of them gets about 20 m^3/h.

According to the rules in force about the ventilation of fixed installations, smoking and restaurant compartments must get about 50 % more fresh air than the above figures. But in view of the small volume of the passenger compartments, and the power needed to heat the fresh air and work the fan, such an increase in the quantity of fresh air is not economically realisable.

It is interesting to get some idea of the power needed for maintaining the temperature in a standard passenger coach.

This is made up of the ventilation requirements, for heating the necessary fresh air, the radiation losses from the coach, and the additional ventilation losses, taking into account the efficiency of the heating system.

For a severe outside temperature of — 20° C, the amount of fresh air must not exceed 1 200 m^3/h brought up to + 20° C, i.e. about 1 030 m^3/h at — 20° C. To raise the temperature of this quantity of air to + 20° C, the temperature of the compartments, needs a power of 16 kW. The losses through radiation in the case of a four axled coach with good heat insulation, fitted with double windows, can also be taken as close to 16 kW. The additional ventilation losses, due to the lack of air tightness of the coach, naturally depend to a great extent on how well the coach is built. They should not exceed 25 % of the real ventilation losses, i.e. 4 kW. This means that for an outside temperature of — 20° C a heating power of 36 kW is necessary to keep the compartments of the coach when empty at a temperature of + 20° C. If, however, the coach is occupied,

the heat from the passengers must be taken into account, amounting to some 80 to 100 W per person. With 40 to 50 passengers, the necessary heating power is therefore reduced to 32 kW per coach.

The efficiency of the heating system, i.e. the ratio between the calorific energy supplied to the coach either directly or by means of some heating medium and the electric power consumed, is practically 100 % in the case of the system with radiators in the compartments whether heated by hot water or by hot air. It can therefore be left out of the calculations. Consequently, to make sure that the passengers are given satisfactory air renewal conditions, the heating power required does not depend upon the heating system used and can only be reduced by very careful insulation of the coach. It is a mistake to think, as is often done, that with heating by means of radiators in the compartments or hot water heating, for equal comfort, there is a lower consumption of power than with hot air heating. On the contrary, it should be remembered that with hot air heating, the new air is brought into the coach after being heated at certain predetermined places, whilst with all other methods of heating, the cold air comes in by every possible inlet, especially when the door and windows are not air tight, which leads to unpleasant draughts.

In this connection, we would also like to call attention to the possibility, not fully utilised to date, of making use of the air from the coach for heating and keeping hot the water tanks. For this purpose, the heating consumption is generally 1 to 4 kW with relatively costly arrangements, which could be avoided by placing the water tanks in a well insulated place and letting the air escaping from the compartments flow over them. Close collaboration between the designers of the vehicle and those responsible for the heating installations could lead to appreciable savings of power consumption in this case, which would reduce operating costs and should be taken into consideration by the railway Administrations.

Close collaboration is also required between the builders of the vehicle and the technician responsible for the heating installation for other reasons in particular in view of determining the power of the fan of the heating installation.

The following brief calculation will make this clear :

It is admitted that the speed at which the hot air comes out of the heating pipes in the compartments amounts to 3 to 4 m/s, which means a pressure of about 1 mm of water. The load losses in the aspiration shutter, in the filter, in the aspiration pipe and in the distribution pipes may be taken as being equal to 5 mm of water in each case. The load loss in the heat exchanger should not exceed 15 mm of water. This gives a total static load of 36 mm of water, and for an amount of air of 1 200 m^3/h, a power for driving the fan of 0.25 H.P. The lighting and battery charging dynamo or the accumulators therefore have to supply a power of about 220 W. With a poor arrangement of the air pipes and too great a flow of air, the power required may be double or even three times as much, so that it becomes necessary to reinforce the fan to an unjustifiable extent, as well as the lighting dynamo and battery. This leads to greater initial costs and additional weight to be pulled. The builders must therefore aim at the maximum economy in this field.

Another important problem is that of the preheating of coaches with electric heating. As there is no one in the compartments during the preheating period, there is no consumption of oxygen. The amount of air brought into the compartments for heating purposes must therefore include just enough fresh air to get rid of the stale air left in the coach. It is therefore advisable, especially when the outside temperature is very low, to make use of a closed circuit, in which 40 to 60 % of the air is constantly circulated, the remainder being drawn in from outside. Economies in the power required for heating and the time taken to raise the temperature are increased by using a 20 to 25 % higher voltage for the reheating installation than the normal heating voltage. This of course provided the heating installation will stand up to the increased voltage.

We will give a simple example to make the position clear. Unfortunately, no exact figures are as yet available for the constant temperatures of the different types of coaches, and the « Research Department for passenger coaches » which proposes to set up on the site of the Vienna Arsenal a Researches and Trials Office (O.R.E.) of the International Railway Union will have the useful mission of determining the thermic characteristics of the different types of coaches. For the present example, we will adopt the hypotheses corresponding more or less to an airtight and well insulated four axled coach. As we have already stated, the calorific losses from this coach, for a temperature difference of 40° C amount to about 36 kW. When the coach is at a standstil, this figure can be brought down to 32 kW. If it is agreed that the calorific losses from the coach are approximately proportional to the difference in temperature, even during the preheating period, we can show the specific calorific losses with sufficient accuracy by the expression :

$$V_1 = \frac{32 \text{ kW}}{40^\circ \text{ C}} = 0.8 \text{ kW } ^\circ\text{C}.$$

Let us suppose that the specific calorific capacity of the coach during the heating up period is about $Q_1 = 1$ kWh/°C. This is a very favourable figure, which is usually exceeded in practice. In the present calculation, we will suppose that it remains constant, although it is influenced, like the calorific losses V_1, by various factors, especially the speed of preheating.

Start from these somewhat arbitrary hypotheses, which are confirmed by practical tests on coaches in service, we get for the temperature constant of the preheating curve :

$$T = \frac{Q_1}{V_1} = \frac{1 \text{ kWh/°C}}{0.8 \text{ kW/°C}} = 1.25 \text{ h} = 75 \text{ min}.$$

With a closed circuit, heating 600 m³ of air per hour is unnecessary. The calorific losses therefore only amount to :

$$V_1 = \frac{24 \text{ kW}}{40^\circ \text{ C}} = 0.6 \text{ kW } ^\circ\text{C}.$$

If we keep the same value for Q_1, we get :

$$T = \frac{1 \text{ kWh/°C}}{0.6 \text{ kW/°C}} = 1.67 \text{ h} = 100 \text{ min}.$$

Starting from the values of V_1 and the heating power, we can calculate the maximum temperature in the compartments :

$$\Delta \vartheta_{max} = \frac{N}{V_1}.$$

In this way we already have the character of the temperature functions. To show these in figure 1, we have used a scale which gives the heating curves in the form of straight lines (S. RITTER : « Die lineare Darstellung der Erwärmungslinie und verwandter Kurven in einem Exponentialraster und ihre praktische Anwendung » (*The linear representation of the heating curve in an exponential field and its practical application*), E und M, 68th year, 1951, No. 19). Table I gives the results of the preliminary studies for the different methods of working and for different outside temperatures. The values given in this table for the heating up periods and the consumption are also given in figures 2 and 3 in the form of curves, using as abscissae the outside temperature and as parameter the method of working. These figures show that the closed circuit is only of real advantage at very low temperatures, but that an increase in the voltage during preheating is always advantageous because it leads to the minimum consumption and shortest heating up time. Unfortunately, it is not possible to increase the heating voltage at will, because the temperature of the hot air must not be too high. The heating power of 48 kW taken as hypothesis is the maximum which can be authorised for a fan output of 1 200 m³/h. This high preheating power, like the closed circuit, should only be used at temperatures below 0° C.

Regulating the temperature of the compartments was done originally in the case of coaches heated by hot air by opening and closing automatically shutters at the air inlets into the compartments. These shutters

TABLE I. — LENGTH OF HEATING UP PERIOD AND CONSUMPTION INVOLVED

Heating power kW	Method of working	$\Delta\vartheta_\infty$	$\Delta\vartheta$ = 10° C		$\Delta\vartheta$ = 20° C		$\Delta\vartheta$ = 30° C		$\Delta\vartheta$ = 40° C	
			t min	Nt kWh	t min	Nt kWh	t min	Nt kWh	t min	Nt kWh
32	without closed circuit	40°	21.5	11.5	51.5	27.5	103.5	55.0	∞	∞
	50 % closed circuit	53°	20.6	11.0	46.8	25.0	82.7	44.1	138	72.6
48	without closed circuit	60°	13.6	10.9	30.4	24.3	52.2	41.8	82	65.6
	50 % closed circuit	79.5°	13.3	10.6	29.0	23.2	47.5	38.0	69	55.2

were controlled by compartment thermostats set at the desired temperature. Later on the automatically controlled shutters were replaced by hand operated shutters. The power of the heating appliance was put in circuit or cut off either as a function of the position of these shutters, or as a function of one or two suitably placed thermostats. The principle on which the temperature was regulated therefore depended essentially on the fact that the hot air was sent intermittently through the compartments, the passengers usually being able to reduce to some extent the amount of hot air coming in. This system did not give complete satisfaction, because when calorific requirements were low, in other words when it was not very cold, only relatively short

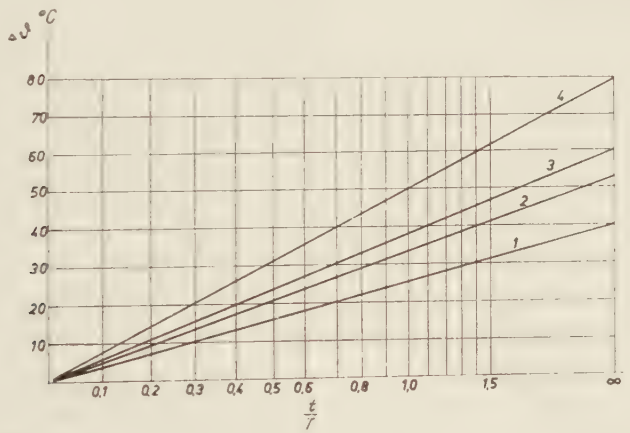


Fig. 1. — Determination of heating up period.

1. 32 kW without closed circuit T = 75 minutes
2. 32 kW with 50% closed circuit T = 100 minutes
3. 48 kW without closed circuit T = 75 minutes
4. 48 kW with 50% closed circuit T = 100 minutes

gusts of air at a temperature of 70 to 100° C were required. But such air temperatures make it difficult to maintain a constant temperature in the compartment. In addition, when the outside temperature rises, less and less fresh air is being taken into the coach.

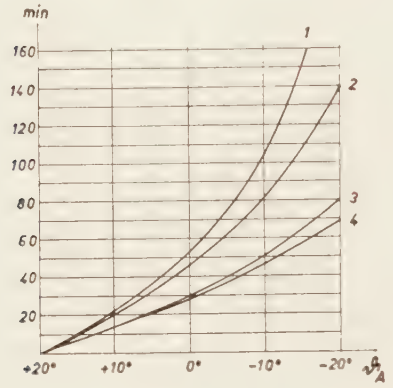


Fig. 2. — Heating up period as a function of the outside temperature.

1. 32 kW without closed circuit
2. 32 kW with 50% closed circuit
3. 48 kW without closed circuit
4. 48 kW with 50% closed circuit

To remedy this drawback, a new regulating system using constant quantities of air has been perfected. With this system, the fan is always revolving and the temperature of the hot air is maintained by putting the heating equipment into or out of circuit as required to keep the temperature of the compartments at the prescribed level. For this purpose, one compartment thermostat and two hot air thermostats have been fitted (a maximum and a minimum thermostat). The former is regulated for the temperature required in the compartment and can make a choice between the two hot air thermostats which are set at different temperatures. If the temperature in the compartment becomes excessive, the compartment thermostat puts into circuit the hot air thermostat with the lower setting, and vice versa. The hot air thermostats are fitted in the hot air pipe, but only penetrate into it to a certain extent, their other part being surrounded by the outside air. Thanks to this arrangement, the thermostats take up an intermediate temperature between that of the outside air and that of the hot air, and they regulate the time the heater is in circuit in such a way that this average temperature is maintained as constant as possible. Figure 4 represents the regulating interval between these two thermostats, taking it that the thermostats show the exact average between the temperature of the outside air and that of the hot air. The active part of these instruments therefore penetrates into the same quantity of a current of hot air as of outside air. The maximum thermostat is set at a temperature of + 25° C. The minimum thermostat is set for + 15° C.

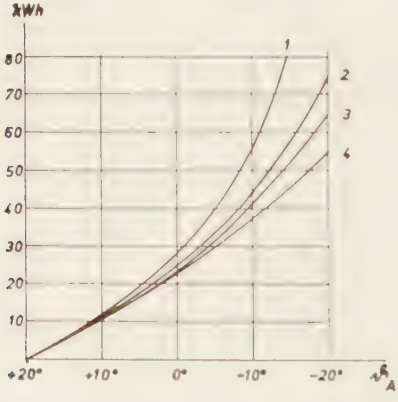


Fig. 3. — Power required for heating up as a function of the outside temperature.

1. 32 kW without closed circuit
2. 32 kW with 50% closed circuit
3. 48 kW without closed circuit
4. 48 kW with 50% closed circuit

The ideal temperature curve 1, which shows the desired variation in the average temperature of the hot air as a function of the outside temperature is shown in figure 4 by a straight line drawn between the calculated point — 20°/+ 60° and the point + 20°/— 20°. Theoretically, this would result in a slightly increasing temperature in the compartment, so that owing to the emission of heat by the passengers, the compartment temperature would be 24.5° C when the outside temperature was + 20° C

The two regulating straight lines 2 and 3 are hypothetically parallel to that of the

temperature curve 1. The regulation zone for the hot air temperature has a constant difference of ± 10° from the ideal temperature curve.

As however calorific requirements do not depend solely upon the temperature of the compartment, but also on a series of other factors, such as the number of passengers, the running speed, the wind, the amount of sunshine, the weight of the quantity of air introduced, etc. the ideal temperature curve may have a different appearance according to the operating conditions. In figure 5, for example, we have shown, side by side with the temperature curve 1, an incurved curve 1', which moreover need not necessarily pass through the point 20°/20°. The upper and lower regulating straight lines must be drawn in such a way that all the ideal temperature curves in practice are within the regulating zone between these straight lines. For this condition to be fulfilled, in the present case, the lower straight line must lie between the points 18°/18° and — 20°/42°. To determine to what extent the minimum thermostat must penetrate into the hot air current, it must not be forgotten that the dilatation of the active part is proportional to the length and temperature.

If we designate by :

l the active length of the thermostat,

$e \cdot l$ the length of penetration into the hot air pipe,

ϑ_L the temperature of the hot air,

ϑ_A the temperature of the outside air,

ϑ_R the temperature at which the thermostat is set,

we can write the following equation :

$$e \cdot l \cdot \vartheta_L + (1 - e) \cdot l \cdot \vartheta_A = l \cdot \vartheta_R,$$

$$e = \frac{\vartheta_R - \vartheta_A}{\vartheta_L - \vartheta_A}.$$

By writing in this equation the above values for the minimum thermostat, we get :

$$e = \frac{18^\circ - (-20^\circ)}{42^\circ - (-20^\circ)} = \frac{38^\circ}{62^\circ} = 0.612.$$

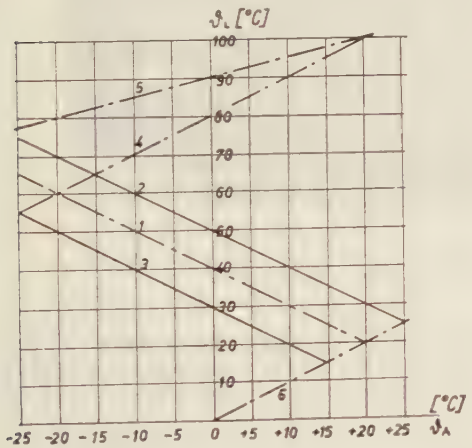


Fig. 4. — Regulation of the temperature at constant regulation zone.

1. Ideal hot air temperature.
2. Upper regulating straight line.
3. Lower regulating straight line.
4. Temperature of the air at full heating power without closed circuit.
5. Temperature of the air at full heating power with 50% closed circuit.
6. Temperature of the air without heating.

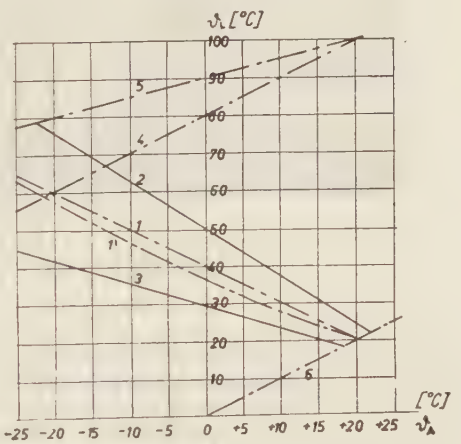


Fig. 5. — Regulation of the temperature in the variable regulation zone.

1,1'. Ideal hot air temperature.
2. Upper regulation straight line.
3. Lower regulation straight line.
4. Air temperature at full heating power without closed circuit.
5. Air temperature at full heating power with 50% closed circuit.
6. Air temperature without heating.

As a result the minimum thermostat must penetrate into the hot air pipe some 61 % of its active length and 39 % of its active length must be surrounded by the outside air. It is set for a temperature of 18° C.

Likewise, the upper straight line must be drawn through the points previously selected 22°/22° — 20°/76°, and the above formula gives :

$$\epsilon = \frac{22^\circ - (-20^\circ)}{76^\circ - (-20^\circ)} = \frac{42^\circ}{96^\circ} = 0.44.$$

and can easily be compensated by small adjustments in service.

In figures 4 and 5 the air temperature curve at full heating power has also been traced. Seeing that for a constant quantity of air the heating power is proportional to the heating of the air, the difference between curve 4 and the regulating curves shows the savings in power obtained by automatic temperature regulation.

If it is admitted that in the most unfavourable case the regulation of the air

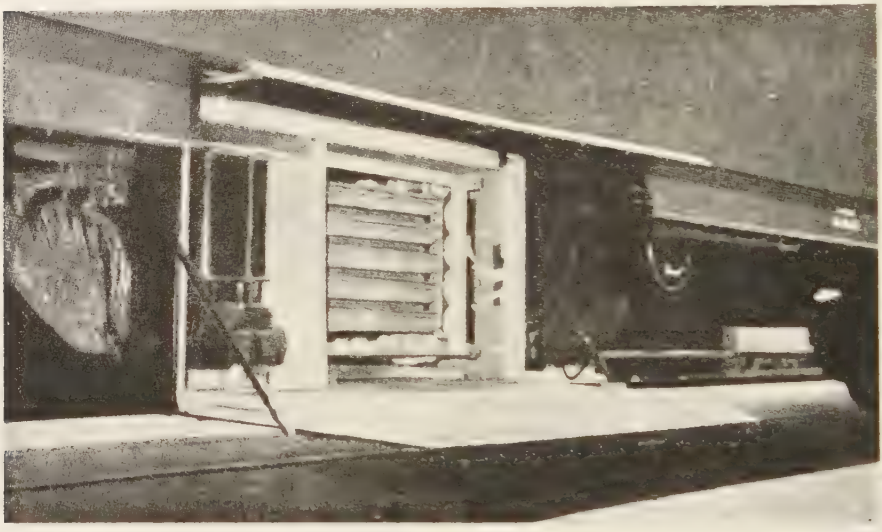


Fig. 6. — Heating coffer under the body of the coach. From left to right : hot air pipe, steam heater, electric heater, fan with motor driving it.

The maximum thermostat will therefore penetrate for some 44 % of its active length into the hot air pipe and be surrounded by the outside air over some 56 % of its active length. It is set at a temperature of 20° C. But it should be noted that the figures given are only an approximation, because the coefficient of thermal exchange and consequently the heating of the thermostats depends upon the air speed and because the insulating layer of the hot air pipe forms an indeterminate temperature zone. The resultant errors are however insignificant

temperature according to the upper straight line is just sufficient to maintain the desired temperature in the compartment, it will be seen from figure 5 that the lower temperature limit lies at — 13° C when working with new air and — 22° C when working with a closed circuit. In any case, it appears to be necessary to make use of a closed circuit at about —13° C. Such low temperatures are rare and do not generally last long, so that in such cases, the lower rate of air renewal can be put up with.

Owing to the various temperaments of

different passengers, and the different conditions prevailing — as they often eat and sleep in the same coach — it is advisable to make it possible for passengers to regulate the heating themselves. For this purpose, it is possible to use hand operated shutters, allowing the current of hot air coming out under each seat to be cut off to some extent. In many cases, it may be useful to provide a switch making it possible to bypass the compartment thermostat and select one or two regulating positions. It is particularly important in such cases to fix these two positions correctly.

To make the heating up period as short as possible, the two thermostats in the hot air pipe are cut out. It is only when the desired temperature in the compartment has been reached that the hot air thermostat begins to act on the heating.

This modern type of regulation assures an agreeable temperature in the compartment and a constant and regular introduction of fresh air, which considerably increases the comfort of the journey. As this fresh air is being constantly introduced when it has already been warmed, the unplesant draughts which occur with other systems of heating when fresh air is brought in are in practice completely eliminated.

In summer, the same installation makes it possible to bring fresh, unheated air into the compartments. The hot air heating system therefore, in our latitude, has practically all the advantages of air conditioning, without its heavy first cost, high power consumption and maintenance costs which are so high that they could only be considered in the case of luxury coaches.

Recently, the Austrian Federal Railways

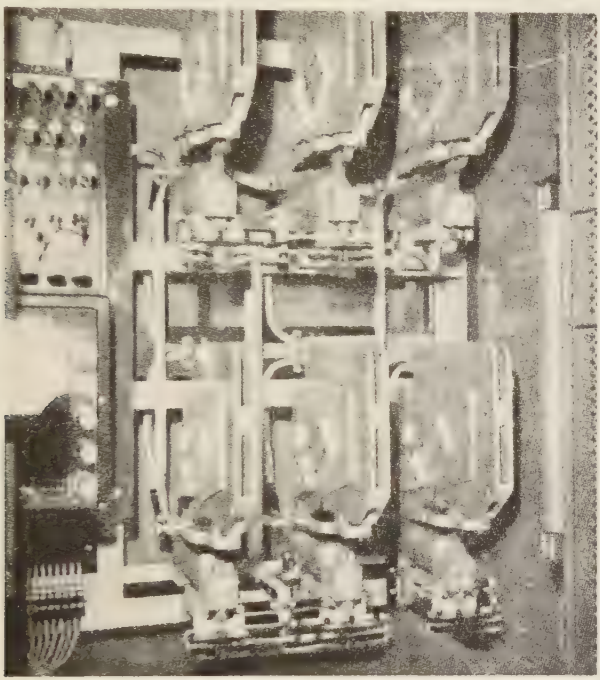


Fig. 7. — Equipment cupboard inside the coach, with selector relays and switches for automatic voltage changeover.

have also decided to use hot air heating in coaches to be used solely on internal services. It then became apparent that the increase in comfort due to hot air heating led to practically no increase in the first cost provided provision had been made for such equipment when designing the coach.

Finally, it appears necessary to stress the advantages of hot air heating for stopping-train and metro coaches, as such coaches are in fact often very heavily loaded and should therefore for hygienic reasons have a plentiful supply of fresh air without draughts. If it is remembered that already a whole lot of motorcars and tourist coaches enjoy hot air heating and that aircraft have air conditioning equipment, it will be seen how necessary it is to equip railway coaches also with modern, hygienic heating. The Austrian Federal Railways have fully understood this and are taking steps to increase comfort by constantly increasing the number of coaches equipped with hot air heating.

[656 .259]

Electronic monitoring of track sections,

by Dr. W. Kaiser and W. Suerkemper.

(*Signal und Draht*, No. 10, October, 1960.)

1. Introduction.

In view of the exacting safety requirements and the desire to increase the economic efficiency and capacity of train operation, there is a constant need for improving and extending the measures which aim at safeguarding and controlling the operation of trains with a minimum of trouble. This also applies to the verification of the occupancy, or non-occupancy, of track sections. In this case, the proving criterion must be supplied by the running train itself. This task can be solved in a particularly elegant way by means of electronic devices.

2. Alternative methods of train intervention.

As regards the action of the train on the track monitoring devices, a distinction must be made, in principle, between intervention at one point only, and intervention over a whole section of line.

2.1. *Intervention at one point only.*

Where the intervention of the train is confined to one point only, the wheels merely initiate, at a given point of the track, an impulse signal which is confined to the time during which the wheel is in contact with the limited zone concerned (ideally, a point). This effect is obtained, e.g., by means of mechanical rail contacts or magnetic impulse emitters.

The mechanical rail contact reacts to the deflection of the rail, caused by the wheel pressure and magnified, e.g., by pneumatic means [1, 2] (*). With the magnetic impulse emitter [3], the passing wheels modify the balance of a bridge formed by uniform magnetic fields so that a polarized armature mounted in the emitter is reversed. These impulse emitters can only work if the wheels of the vehicles consist of permeable material.

(*) The figures between brackets refer to the Bibliography at the end of this article.

2.2. *Intervention over a section of line.*

If the intervention of the vehicle extends over a shorter or longer section of track, one may speak of a linear effect.

A case in point is the track circuit where the rails of a given section of track are separated from those of adjacent track sections by means of so-called insulated rail joints [4, 5]. The voltage applied to one end of the insulated track section energizes a track relay connected to the other end. As soon as a train enters the section concerned, the track relay is shunted by the axles; it drops and reports the section as occupied.

Track circuits are operated, in different countries, with D.C. or A.C. voltages of, e.g., 50, 75, 83 1/3 or 100 c/s. A special case is that of installations working with alternating voltages of higher frequencies (e.g., 10 c/s) and a correspondingly tuned track relay [6, 7]. In this case, there is no need to provide insulated rail joints as, due to the damping effect of the longitudinal impedance of the line of rails, the voltage decreases rapidly on either side of the feed point so that the track relay can only be influenced within a small, albeit not strictly defined, zone of a length depending on the frequency chosen, on the rail damping coefficient, on the ballast resistances, on the sensitivity of the track relay, etc.

3. Definition of the problem.

The conventional devices referred to above are not in all respects satisfactory. It has, for instance, been found difficult to render the mechanical rail contact, which depends on the wheel pressure, sufficiently sensitive to lightweight vehicles, i.e. vehicles causing very slight rail deflections, without precluding accidental action. With track circuits, on the other hand, the length of the proving section is limited, and such factors as the ballast resistances at the sleepers and the contact resistances between rails, wheels and axle come into play. Moreover, track circuits can only be used if the rails are insulated, and continuously welded track must be dissected by insulated joints.

To design a track monitoring device able to meet all reasonable and indispensable requirements, it is, first of all, necessary to formulate these requirements [8]. The installation as a whole must conform to the following conditions :

a) the installation must be extremely reliable (with a minimum number of breakdowns), and must preserve this reliability with trains running at maximum speed as well as with stationary or starting trains;

b) the installation must be largely immune to fluctuations in the working voltage, and must not endanger the running of trains if the power supply should fail;

c) the installation must conform to the general safety conditions, i.e., any defect must act on the safe side.

In addition, the track-mounted parts of the equipment must conform to the following conditions :

d) they must react irrespective of the materials of rails and permanent way (wooden, concrete or steel sleepers), of the type and condition of the wheel (diameter; solid or spoke wheel; metal wheel made of non-permeable material; degree of wear), and of the transverse movements of the wheels on the rails;

e) apart from the wheels, the devices must not be affected by any other metallic parts of the vehicle (rail brake; lavatory pipe; hanging chain);

f) the device must be indifferent to extraneous stray fields (caused by return traction currents on electrified lines; vehicle magnets of the inductive train stopping device; wheels with residual magnetism) and to mechanical vibrations (vibrating rail);

g) the device must not be affected by climatic conditions (temperature; water, snow, ice);

h) the device should, if possible, not contain any moving parts so as to prolong the service life and reduce servicing and maintenance requirements;

i) power requirements should be low so that power can, if necessary, be supplied over long distances;

k) the device should be so designed that it can easily be installed without difficult adjustment work, without any considerable modifications to the permanent way, and without impairing the structure gauge.

These conditions can only be fulfilled by electronic devices and installations. An all-electronic, transistorized track section monitoring installation has been developed by Standard Electrik Lorenz AG (SEL).

4. Design and operation of the installation.

The installation consists of one or several « electronic rail contacts » (outdoor installation) and an electronic interpretation device (indoor installation) electrically connected with each other.

4.1. *Electronic rail contact.*

The principle on which the electronic rail contact is based is shown in figure 1. The installation comprises a generator, an amplifier and an impulse emitter consisting of a transmitter coil and a receiver coil. The transmitter coil is inclined at a certain angle to the rail, whilst the receiver coil is vertical and is connected with

the rail web by means of a pole shoe of high magnetic permeability.

The generator oscillates at, e.g., 5 kc/s. The transmitter coil fed by the generator generates a periodic magnetic field. Part of this field is received by the receiver coil. When the wheel of a vehicle passes between the two coils, the metal surface of the

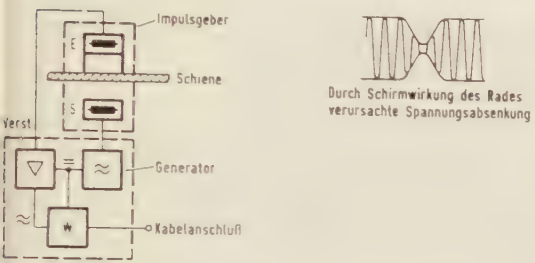


Fig. 1 — Principle of the electronic rail contact.

E = receiver coil.
S = transmitter coil.
W = junction between A.C. and D.C. voltages.

N. B. — Impulsgeber = impulse emitter. — Schiene = rail. — Verst. = amplifier. — Kabelanschluss = cable terminus. — Durch Schirmwirkung... = voltage drop caused by the screen effect of the wheel.

wheel produces a screen effect, and the alternating voltage induced in the receiver coil will decrease. By means of a special arrangement of transmitter and receiver coils, it has been possible to ensure that the receiver coil is placed in the diagonal arm of a bridge of flux lines so that the voltage drop during the passage of a wheel amounts to nearly 100 %. In particular, the arrangement is so designed that, by and large, the screen effect is provided by the wheel flanges only. For that reason, metal parts reaching down to the top of the rail head only have little or no effect on the impulse emitter. The electronic rail contact will therefore not be affected by the rail brakes fitted to lightweight vehicles such as rail buses, which are in contact with the rail head during the brake application.

Each passing wheel will cause the electronic rail contact to emit an impulse; but this impulse provides no indication of the direction in which the wheel is moving. In many cases, however, information on the direction of running is desirable or even necessary. In this case, it is necessary to use two impulse emitters with overlapping zones of action. For this purpose, impulse emitters are mounted on each rail of the track, slightly staggered in relation to each other (fig. 2). Together with two receiver amplifiers and a joint generator these two impulse emitters constitute a « set of electronic rail contacts ». This arrangement has the incidental advantage that the inadvertent or wanton introduction of metallic objects (e.g. tools) into one of the impulse emitters is automatically recognized as a faulty intervention.

The basic diagram of a set of electronic rail contacts is shown in figure 3. The generator jointly assigned to the two impulse emitters feeds both transmitter coils, the main windings of which are connected in series. These windings represent the inductance, whilst the capacitor between

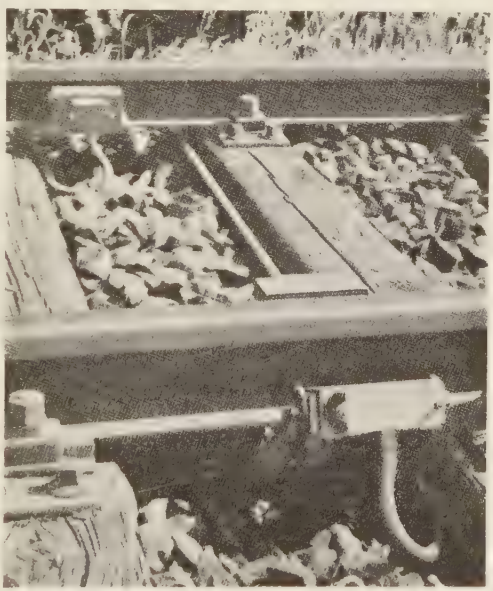


Fig. 2. Arrangement of two impulse emitters forming a set of electronic rail contacts on the track.

the transistor collectors represents the capacitance of the oscillating circuit which determines the frequency. The excitation of the oscillations is produced by additional reaction windings of the transmitter coils which are connected to the base points of the two push-pull action transistors. In this arrangement, both transistors assume the function of switches, inasmuch as they alternately connect the battery voltage to one and the other of the main windings of the transmitter coils. From this rectangular voltage, the sinusoidal fundamental (in our example, 5 kc/s) is filtered out by the oscillating circuit. The two transmitter coils are connected with each other through the reaction windings which are connected in parallel. This arrangement ensures that the voltages encountered at the two main windings have the same amplitude but have a phase displacement of 180°. If only one impulse emitter is connected to the generator, the second transmitter coil must be simulated in the generator.

The receiver coil of each impulse emitter equally belongs to an oscillating circuit which is attuned to the transmitter frequency and which, to a great extent, suppresses voltages of other frequencies that may be received. The two oscillating circuits of the two-stage receiver amplifier contribute to the improvement of selectivity. The amplifier boosts the receiver signal to such an extent that the latter is able to bridge the cable loss of about 20 *d*B. With conductors of 0.9 mm dia., this value corresponds to a distance of approx. 8 km.

The duration of the impulse is inversely proportional to the speed of the train. But even at a speed of 220 km/h, the impulse duration is still about 10 millisec. Since electronic systems are able to interpret even much shorter impulses with complete reliability, the electronic rail contact works reliably at all train speeds which can be encountered in practice. The amount of wheel and rail wear permissible in railway operation has but little effect on the impulse so that no faulty interven-

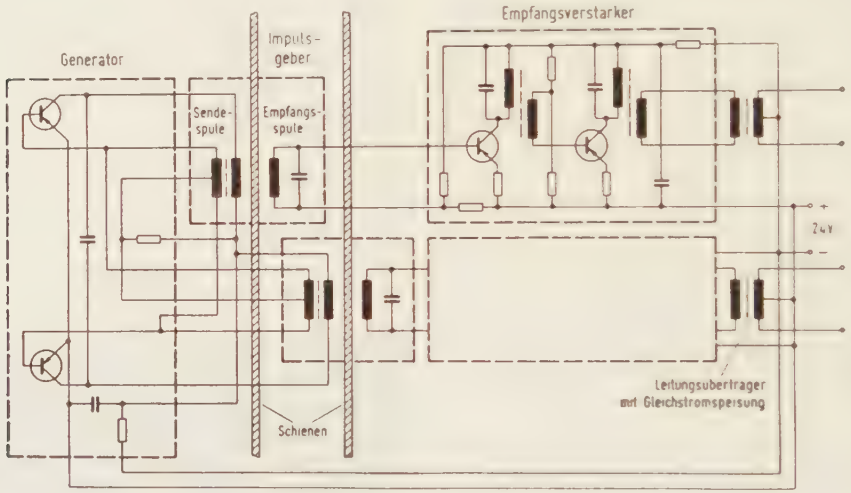


Fig. 3. — Basic circuit diagram of a set of electronic rail contacts.

N. B. — Sendespule = transmitter coil. — Impulsgeber = impulse emitter. — Empfangsspule = receiver coil. — Empfangsverstärker = receiver amplifier. — Schienen = rails. — Leitungsübertrager mit Gleichstromspeisung : D.C. fed repeater.

tion can occur for that reason. Similarly, the effects of extraneous stray fields have been reduced, by a suitable choice of transmitter output, impulse emitter design and amplifier band width, to such an extent that — even under the most unfavourable circumstances — no inadvertent impulses can be produced by them.

through the receiver signal lines so that no more than two pairs of conductors are required for the electronic rail contact set. The line repeaters then serve as separators for the D.C. working voltage and the A.C. receiver voltage. If the distance between the electronic rail contact set and the interpretation device is great,

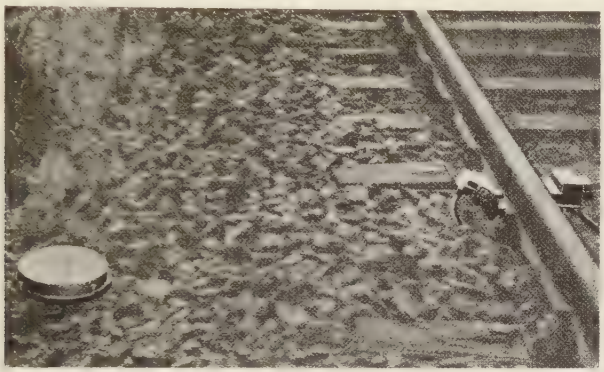


Fig. 4. — Transmitter and receiver coil mounted on the rail. The remainder of the equipment is housed in the cast-metal casing adjacent to the track.

4.2. *Electronic interpretation device.*

Depending on the task, the electronic interpretation device must be composed of different units (amplifier, pulse shaper, counters, etc.). The mode of operation of certain combinations of units will be explained in conjunction with the discussion of some practical examples (Sections 5 and 6).

4.3. *Electric connections and current supply.*

Normally, the electronic rail contact must be connected with the interpretation device by two pairs of conductors, and the electronic rail contact set by three, where one pair serves for the current supply and the other(s) for the receiver voltages of the impulse emitter(s). The existing line repeaters with central tapping (fig. 3) enable the working voltage to be transmitted

it may be advantageous to use, for the two impulse emitters, two different frequencies (e.g., 5 and 8 kc/s, respectively). In that case, it will be possible to use the two conductors of one pair, separated by capacitors as far as D.C. is concerned, for the simultaneous transmission of the D.C. working voltage as well as the two A.C. receiver voltages, using the two-wire frequency separation system.

4.4. *Structural design.*

Transmitter and receiver coils of the impulse emitter are housed in a light-metal box, and are cast-embedded. The impulse emitter is fastened by claws to the foot of the rail and is so designed that its installation does not call for any modifications to the track. As the stagger of the two impulse emitters of an electronic rail contact set need not be great, the two

emitters can be mounted between the same two sleepers without altering the sleeper arrangement itself (fig. 2).

All the other components of an electronic rail contact, or electronic rail contact set, are housed in a cast-metal casing by the side of the track (fig. 4). They are placed in two receptacles filled with casting resin: one of them contains the generator whilst the other contains the two selective receiver amplifiers. Generator and amplifiers work with silicon transistors.

All the parts of the electronic rail contact have been selected for their particularly high resistance to climatic influences. The outdoor parts thus remain in working order over a temperature range from — 40 to + 100° C; they have a long service life and require practically no maintenance. As there are no mechanically moved parts, there is no wear. Since the parts are castembedded, they are largely immune against weather influences.

To enable the interpretation devices to be composed in accordance with the specific requirements, their component parts are designed as plug-in units (*). These consist of sheets of insulating material with printed circuit (fig. 5). The plug-in units are mounted on a trough-shaped frame; one such frame may, e.g., accommodate an entire interpretation apparatus for two electronic rail contact sets, complete with proving equipment. Figure 6 shows a fully utilized frame. As the interpretation apparatus is normally indoor-mounted, it is sufficient to design it for a temperature range from 0 to + 35° C. Interpretation devices destined for portable equipment, used e.g. during Engineer's possessions, are of special temperature-proof design.

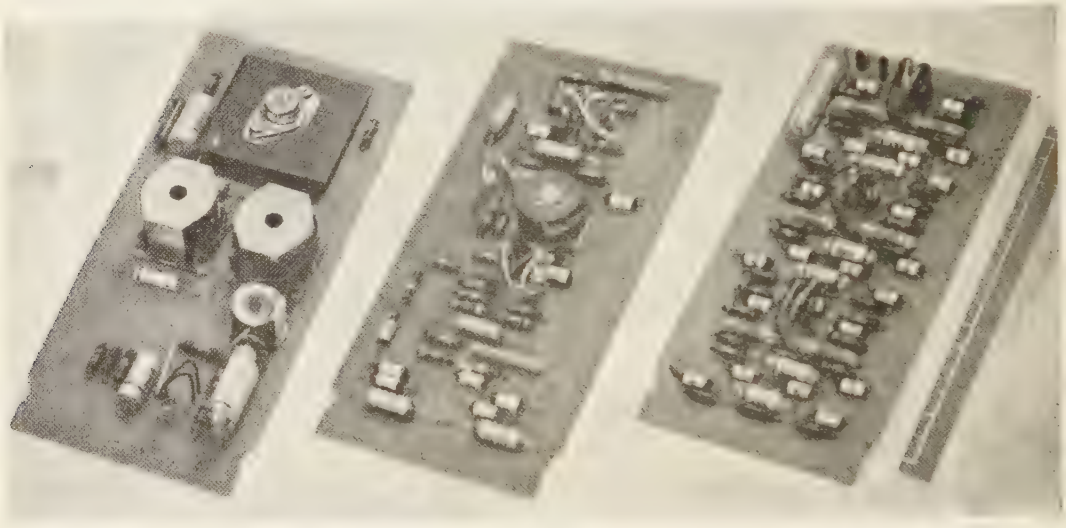


Fig. 5 Examples of plug-in units: Left: Receiver amplifier with rectifier. Centre: Proving unit. Right: Three binary counter stages.

(*) In the definite design, the components are no longer of the plug-in type but are permanently inter-wired on the frame which becomes a plug-in unit of its own.

5. Examples of applications with single-point monitoring systems.

5.1. *Train approach announcing device.*

As figure 7 shows, a train approach announcing device destined to announce the approach of a train, e.g. to a gate keeper or to a permanent way gang, has a very simple connection scheme. An electronic rail contact is mounted on the track, and, when in the normal position, transmits to the interpretation apparatus a continuous audio-frequency signal. When the impulse emitter is passed by a vehicle, the audio-frequency signal is momentarily reduced to a very small value, whenever a wheel is passing. The passage of each wheel will therefore give rise to an impulse behind the detector and the low-pass in the interpretation set. Since the shape and duration of the impulse depends, inter alia, on the speed of the train, a pulse shaper is provided which scans the impulses received at a threshold value of 50 % of the total amplitude and transforms them into rectangular pulses which, irrespective of the train speed, have a constant slope. The first impulse initiates, by means of the interpreter relay, an optical or acoustic signal. To prevent this relay from reacting to the impulses of all the wheels separately, a storage device has been inserted. For the use of the interpretation equipment as a train approach announcer for permanent way gangs, a portable type is also available.

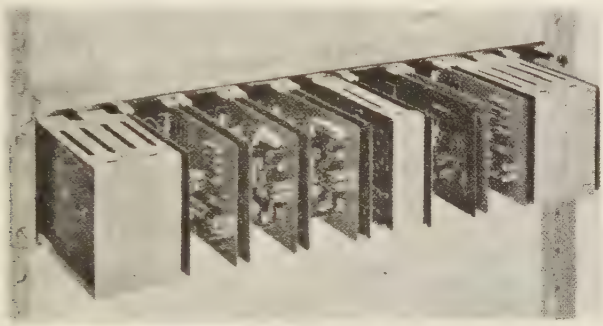


Fig. 6. — Fully utilized trough-shaped frame for plug-in units (prototypes). Some of the units are shown without their holding covers.

5.2. *Speed meter.*

By means of two electronic rail contacts mounted at a given distance from each other, it is possible to monitor the speed of a vehicle by measuring the time required by a wheel to cover the section between the two impulse emitters. The basic diagram of this speed meter is shown in figure 8. The impulses supplied by the two electronic rail contacts follow different paths within the interpretation unit until they reach a data converter which ensures that the output variable at A is analogous to the equation $v = s/t$.

The electronic data converter works so rapidly that the measuring distance can be kept smaller than the smallest distance between axles encountered on railborne vehicles. The output variable at A will then indicate the speed of each wheel of the train, one by one. In this way, it is possible to ascertain not only the *mean* speed of the whole train but also the variation in the speed of the train (acceleration or deceleration) during its passage. This

feature may be important in a number of cases, e.g. where it is desired to adapt the warning time at the approach to gate-protected level crossings to the speed of the train. The indication of the measured speed may be of the analog type (dial instrument) or of the digital type (e.g. by means of numbers appearing on a luminous panel). If, for any reason, it is necessary to preserve a record of the measured speed, the instrument may be connected to a number printer with date and clock time indication.

During hump shunting in marshalling yards, the problem arises of braking individual wagons in accordance with their speed [9, 10, 11]. Here, too, the speed meter is useful inasmuch as it yields the output variable required for the control of the retarders.

A further application occurs on sections of line where a speed limit is in operation.

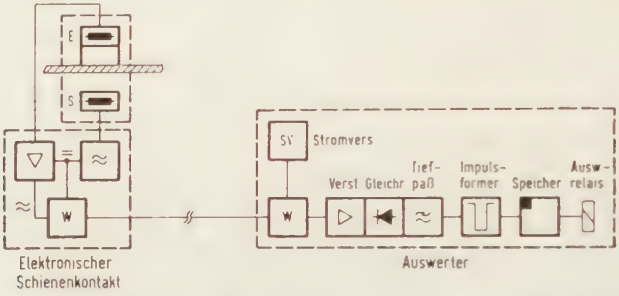


Fig. 7. — Block diagram of a train approach announcer.

N. B. — Elektronischer Schienenkontakt = electronic rail contact. — Stromvers. = current supply. — Verst. = amplifier. — Gleichr. = detector. — Tiefpass = low-pass. — Impulsformer = pulse shaper. — Speicher = store. — Ausw. relais = interpreter relay. — Auswerter = interpretation unit.

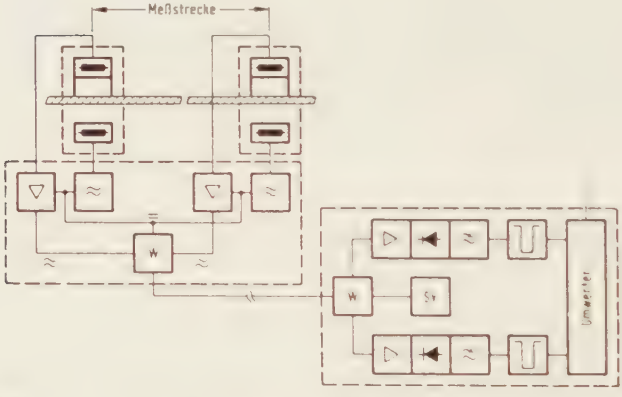


Fig. 8. — Block diagram of a train speed measuring apparatus.

N. B. — Messtrecke = measuring distance. — Umwerter = data converter.

Where a speed limit must be strictly observed, the speed meter may be connected to a specially mounted 2 000 c/s « Indusi » track magnet so that, if the train speed is excessive, a locomotive fitted with « Indusi » equipment can be automatically braked.

6. Examples of applications with linear monitoring systems.

Although the electronic rail contact can only be influenced at one specific point, it is still possible to obtain a linear monitoring system by jointly evaluating the information supplied by two or more suitably spaced impulse emitters. Compared with electronic track circuits, this arrangement has the advantage that the ends of the track section concerned are clearly determined by the electronic rail contacts. Moreover, the track section can, in theory, be made as long as may be desired.

6.1. *Simple axle counting circuit.*

The principle of linear monitoring is best illustrated by the simplest design of an axle counting circuit. The two electronic rail contacts installed at the beginning and end of the track section concerned are connected to a joint interpretation unit (fig. 9). The impulses received from the *entry point* of the track section add to, and those from the *exit point* subtract from, the total count of an adding and subtracting counter. When a train passes over the section, the numbers of axles entering the section are first registered by the counter and are later subtracted again as they leave the section. If the final result is zero, the section is *clear*. The function of the counter thus merely consists in informing the interpreter relay whether or not any axles are within the section, irrespective of the number of axles passing. It is therefore sufficient to use a binary counter which, for great numbers, is less expensive than a decade counter. The shape of the impulses encountered at the different points of the interpretation unit is also shown in figure 9.

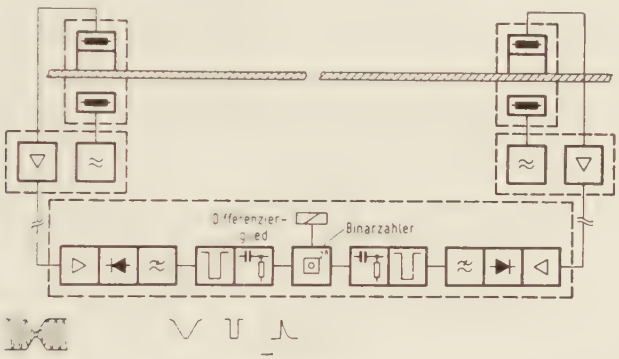


Fig. 9. — Block diagram of simple axle counting circuit.

N. B. — Differenzierglied = differentiating organ. — Binärzähler = binary counter.

The simple axle counting circuit reliably accounts for passing trains. But if, at any of the monitoring points, the direction of running is reversed, this will lead to erroneous counts since one electronic rail contact alone is unable to distinguish between directions of running. As the counter is unable to add and subtract simultaneously, the simple axle counting circuit is subject to the further limitation that the

train must not be longer than the track section concerned. These limitations disappear with the direction discriminating axle counting circuit.

6.2. *Direction discriminating axle counting circuit.*

The following is a more detailed description of a direction-discriminating axle counting installation which has been successfully tried out since March, 1959. Figure 10 shows the general arrangement of this installation. At each end of the track section concerned, a set of electronic rail contacts is installed which, when passed by an axle, transmits to the interpretation unit two separate impulses, emanating from the two slightly staggered impulse emitters of the set. The sequence of the two impulses indicates the direction in which the axle is running.

The interpretation unit contains, for each of the four impulse emitters, separate channels which terminate in pairs in two direction discriminators. These ensure that all the axles entering the section, no matter from which side, are added by the counter whilst all outgoing axles are subtracted. The counter will thus, at any time, show the exact number of axles then in section, even if a vehicle should pass repeatedly over a monitoring point in opposite directions (shunting movements; swinging axles).

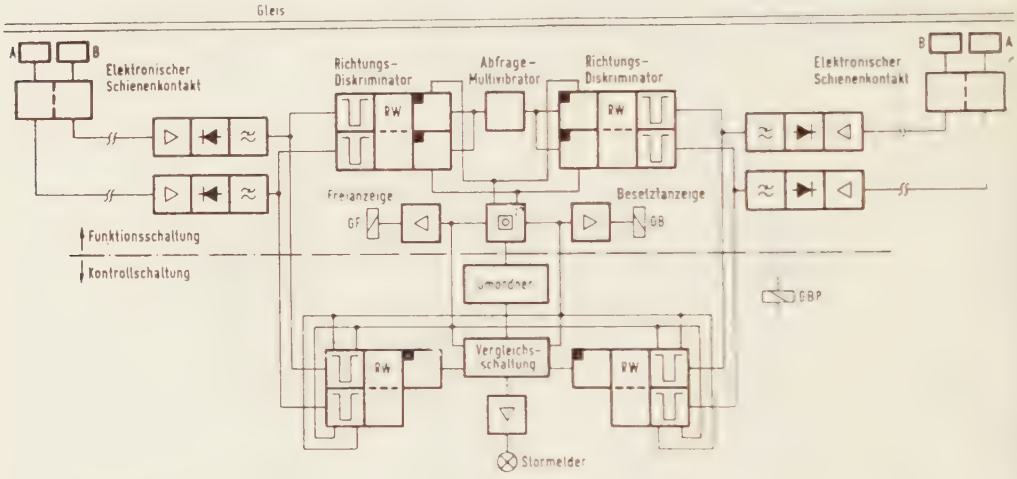


Fig. 10. — Block diagram of axle counting circuit with direction discrimination.

N. B. — Funktionsschaltung = working equipment. — Kontrollschaltung = proving equipment. — Elektronischer Schienenkontakt = electronic rail contact. — Freianzeige = « track clear » indication. — Besetztanzeige = « track occupied » indication. — Richtungsdiskriminator = direction discriminator. — Abfrage-Multivibrator = interrogating multivibrator. — Umordner = data converter. — Vergleichsschaltung = comparator. — Störmelder = trouble indicator. — Richtungsweiche = direction separator. — Gleis = track.

6.2.1. *Direction discriminator.*

As figure 10 shows, the direction discriminator consists of two pulse shapers, a direction separator, and intermediate storage devices for the entry and exit criterion, respectively.

Figure 11 shows the circuit diagram of a direction discriminator. The receiver impulses emanating from the amplifiers appear at the input points A and B of the pulse shapers (Schmitt triggers). The rectangular pulses at points C and D are evaluated in different ways. The pulse

at D shifts the emitter potential of transistors Ts5 and Ts6 in the positive direction so that the direction separator can be passed. In contrast, the pulse at C is differentiated by a repeater placed in the collector circuit of transistor Ts2. The secondary side of the repeater consists of two opposing windings so that the pulses at the base terminals E and F of the transistors Ts5 and Ts6 belonging to the direction separator are of opposite polarity. The duty points of Ts5 and Ts6 are so chosen that only that transistor is open at which the emitter potential (point G) is shifted by the pulse from D in the positive direction and at whose base (E or F) a negative pulse is encountered *simultaneously*. Now, since the rectangular pulse at C, with the front face at F and the back at E, always yields a negative pulse, it is the phase position of the pulse at G which decides whether Ts5 or Ts6 is opened. But the position of the pulse at G is dependent on whether the receiver impulse. A arrives *before* or *after* the receiver impulse B, i.e. whether the train *enters*, or whether it *leaves*, the section concerned. In the former case, an impulse is received at H, and in the latter case at I, registering an incoming or an outgoing axle, respectively.

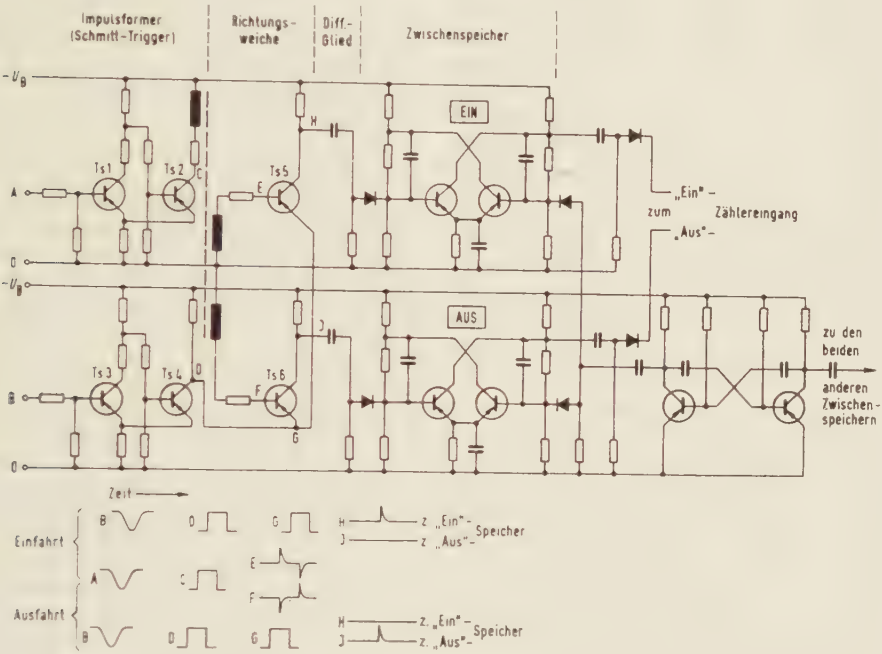


Fig. 11. — Basic circuit diagram of direction discriminator, with indication of pulse shapes encountered at different points of the system.

N. B. — Impulsformer = pulse shaper. — Richtungsweiche = direction separator. — Diff. Glied = differentiating organ. — Zwischenspeicher = intermediate storage device. — Einfahrt = entering. — Ausfahrt = leaving. — Zeit = time. — z. « Ein » Speicher = to « entry » store. — z. « Aus » Speicher = to «exit » store. — zum « Ein » Zählereingang = to « entry » counter inlet. — zum « Aus » Zählereingang = to « exit » counter inlet. — zu den beiden anderen Zwischenspeichern = to the other two intermediate stores. — Ein = in. — Aus = out.

The impulse stored in the intermediate storage cell is deleted by means of a con-

tinuously working interrogator multi-vibrator which supplies, through a differentiator, positive impulses to the right-hand side of both storage devices. An occupied storage cell will then drop back to its zero position and transmit an impulse to the counter. The frequency of the interrogator multi-vibrator is considerably higher than the maximum pulse recurrence frequency determined by the axle spacing and the maximum train speed. Since, at any one time, only one of the two intermediate storage cells can be occupied by an impulse, it is possible to arrange for the two storage cells to be interrogated by a single multi-vibrator.

If an impulse is stored simultaneously on the left-hand and right-hand side of a cell, the interrogating impulse remains ineffective, due to circuiting arrangements not shown here. The storage cells are then only interrogated during the next period of the interrogation frequency.

The interrogator multi-vibrator acts on the direction discriminators alternately. It thus forms, in conjunction with the intermediate storage cells, a pulse separator inasmuch, as in the event of a simultaneous arrival of impulses at both direction discriminators, first one and then the other impulse is passed on to the counter. This is necessary because the counter is unable to accept more than one impulse at any one time.

For the purpose of correct counting, it is immaterial at which point of the rail, in relation to the monitoring point, a wheel changed its direction of running; it is therefore also possible reliably to account for swinging axles. If the wheel affects but one of the two impulse emitters belonging to a set of electronic rail contacts, no impulse will pass through the direction separator, and the track occupancy is reported by the proving device only (cf. Section 6.23).

6.22. *Counter.*

The capaciy of the binary counter depends on the number of stages. Sets of three counter stages are combined in a single plug-in unit (fig. 5). One such unit thus corresponds to a counting capacity of $2^3 - 1 = 7$, whilst two units can count to $2^6 - 1 = 63$, three units to $2^9 - 1 = 511$, and four units to $2^{12} - 1 = 4\,095$. Normally, the counters are equipped with three plug-in units.

When the counter reading is zero, relay GF is energized, and the track is reported clear. If one or more axles are registered, relay GB is energized, and the track is reported as occupied.

6.23. *Proving device.*

The safety requirements on railways are such that any fault in the installation must always act on the safe side, and must be detected not later than on the occasion of the next train movement. In this connection, it is assumed that two faults never occur simultaneously. To meet these conditions, the axle counting installation has been safeguarded by certain special measures. The electronic rail contact as well as the input system of the interpretation unit up to the direction discriminators work with carrier frequencies on the closed circuit principle. Any interruption in this part of the system is interpreted as an impulse, thus causing the « track occupied » relay GB to be energized and the « track clear » relay GF to drop. In addition, the trouble indicator signal lights up.

More difficult is the safeguarding of the digital circuits which begin at the direction discriminators. Here, the safe condition can only be ascertained when the equipment is working. The *static* proving method made possible by the use of the closed circuit carrier frequency system must therefore be replaced by a *dynamic* method. This consists in proving that the entry or exit of n axles has in fact been registered by the counter in correct number and in the correct direction. This task is fulfilled by direction proving devices which are connected to the input side of each direction discriminator and are designed exactly like the latter but for the fact that they emit impulses for entering axles only.

Thus, each entering axle gives rise to an impulse at the outlet of the direction discriminator as well as at the outlet of the direction proving device. If the axle has been counted correctly, the counter will release, via the data converter, a return impulse which is compared, in the comparator unit, with the impulse received from the direction proving device. If one or the other of these impulses has not been received, relay GB will be energized and relay GF will drop. At the same time, the trouble indicator lamp will light up. The proving device has the effect of converting the digital parts of the system into a closed circuit system. Any fault within this system, be it in the working components or in the proving apparatus, will always have the same effect as a « track occupied » report. In addition, the special trouble indicator lamp will indicate a defect in the installation.

A feature of this control system is the fact that the proving process does not concern each component individually but the system as a whole. The dynamic control is confined to the counting of entering axles since, if an outgoing axle fails to register, the section automatically continues to be treated as occupied. Similarly, the track section is treated as occupied if the counting limits are exceeded, either by subtraction beyond zero, or by addition in excess of the capacity available.

Relays GF and GB are proved by a third relay, viz., the track occupancy proving relay GBP.

6.24. *Technical data of an axle counting circuit with direction discrimination.*

Current supply	24 or 60 V, ± 10 %
Power absorbed	approx. 30 W
Temperature range:	
Electronic rail contacts	— 40 to + 100° C
Electronic interpretation unit (indoor design)	° to + 35° C
Maximum train speed	practically unlimited
Counter capacity	ad libitum
Normal equipment	up to 511 axles
Conductors connecting the electronic rail contacts and interpretation unit	telecommunication cables: 2 × 2 × 0.9 or 1.4 mm dia. 1 × 2 × 0.9 or 1.4 mm dia.
With converter, maximum distance with conductors of 0.9 mm dia.	approx. 8 km

6.3. *Possible applications of the axle counting circuit.*

The axle counting circuits here described can be used for many different purposes, e.g. as « track clear » indicators for the safeguarding of level crossings, for the automatic block system, for remote control, etc., or as axle counters to provide an indication, e.g. in hump cabins, of the degree of track occupation in sidings, etc.

6.31. *Protection of level crossings.*

On the approach of a train, level crossings of railway and roads must be protected either by the operation of a flashlight installation or by the closing of a barrier. The requirements, which such installations must meet, depend on the type of line and the specific operating conditions. In all cases, however, they must provide adequate safety for railway as well

as road traffic, yet must not unnecessarily impede the traffic on the road. For this task, the axle counting circuit is very well suited. Figure 12 shows the block diagram of the installation for a double-track railway. On reaching the electronic rail contacts I or III, the first axle of an approaching train causes the operation of the flashlights or the closing of the barrier. In addition, the counter of the corresponding interpretation unit will register the number of entering axles and will disconnect the level crossing protection devices when the last axle has passed the electronic rail contact II or IV.

For single-track lines, the equipment must, in addition, comprise the selection apparatus shown in broken lines in figure 12. In that case, all the four rail contacts must be mounted on the one track. Through the selection equipment, the interpretation unit receiving the first impulse, i.e. I/II for a trip from left to right, and III/IV for a trip from right to left, will block its opposite number so that the freeing of the level crossing is not unnecessarily deferred until the train has cleared the last electronic rail contact beyond the level crossing (III or I).

Whether or not the installation is to work with direction discrimination, i.e. whether the moniriting points I to IV must

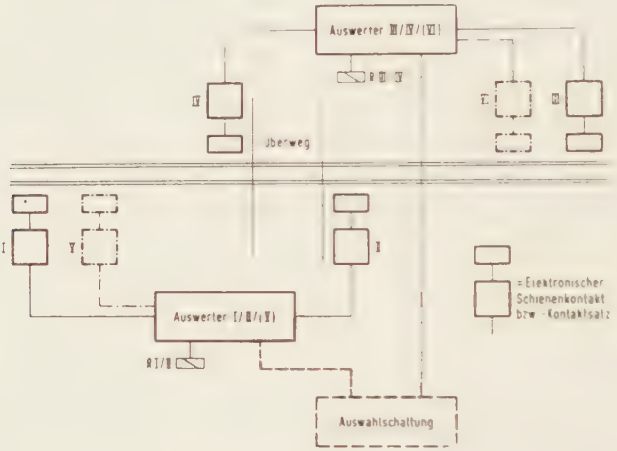


Fig. 12. — Axle counting circuit with direction discrimination serving as level crossing protection device on a double-track line. For single-track lines, the units shown in broken lines are additionally required. The units shown in chain-dotted lines serve as speed meter devices.

N. B. — Auswerter = interpreter device. — Auswahlschaltung = selection unit. — Elektronischer Schienenkontakt bzw.-kontaktsatz = electronic rail contact or set of contacts.

be equipped with electronic rail contacts or with sets of such contacts, will depend on local conditions. But if shunting operations take place in the vicinity of the level crossing, the axle counting equipment must of necessity include direction discriminators.

If a line equipped with level crossing protection devices of this kind is used by trains with greatly different speeds, and the monitoring points I and III must, because of the fast trains, be placed a long distance away from the crossing, a slow train would hold up road traffic for an

unnecessarily long time. This can be avoided by measuring and interpreting the speed of the train. For this purpose, the electronic rail contacts V and VI are installed a short distance from the monitoring points I and III, respectively, and the interpretation unit is equipped with additional speed measuring devices (cf. Section 5.2). The level crossing protection devices will then, depending on the speed, be switched in either at once or after a time lag.

6.32. *Devices indicating the degree af track occupation.*

In certain cases, it is desirable to know the exact number of axles occupying a given section of line. If it is, for example, desired to know whether a siding in a marshalling yard is already fully occupied or whether it can still take more wagons, it is advisable to use an axle counter with an interpretation unit containing a binary-decade converter or a decade counter. The counter can provide a direct number indication and can, in addition, by means of a supplementary device, indicate the full occupation of the siding when the maximum permissible number of axles have entered. If the siding is accessible from one side only, the equipment may remain confined to a single monitoring point with direction discrimination, i.e. a single set of electronic rail contacts.

6.4. *Multiple utilisation of axle counting circuits.*

If a line consisting of several track sections is to be proved from end to end, the axle counting circuits of the different sections must follow each other without interruption. It follows that the exit monitoring point of one section must, at the same time, serve as the entry monitoring point for the next section so that it is logical to use the electronic rail contacts for a dual purpose. If the track sections concerned are under the control of one and the same control point, it is, in this case, also possible to obtain partial dual-purpose utilisation of the interpretation units, viz., up to and including the direction discriminators.

Often the task consists in proving, not a number of sections of a continuous track, but a whole complex of junctions. In this case, the axle counting circuit is merely intended to indicate whether the junction zone is clear or occupied, irrespective of the direction of the trains. Such tasks are encountered at points, crossovers and humping installations. One may then use either multiple-utilized or mutually independent electronic rail contacts according to whether only one, or several, entry or exit monitoring points can be passed by trains at one and the same time. In the interpretation unit, a counter common to all the monitoring points serves to prove the entire junction zone. The interrogator multivibrator is then replaced by an interrogating ring distributor which scans the different intermediate stores and corrects the counter reading accordingly.

7. Summary.

The article describes the mode of operation and the design of a novel-type electronically working rail contact which uses the screen effect of passing wheels as a criterion. Examples of applications include single-point monitoring devices such as train approach accouncing devices, speed meters, etc., as well as linear monitoring devices such as axle counting circuits. Particularly important are the axle counting installations with direction discrimination which permit reliable counting even under unfavourable conditions, e.g. with swinging axles. The use of such installations for « track clear » indications and as axle counters is explained.

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[656 .212 (42)]

Automatic marshalling yards.

Methods being used, and results achieved in the automation of gravity marshalling yards operating under conditions applying to British Railways,

by J.C. Kubale,

Director & Manager, Associated Electrical Industries — GRS Limited.

(*The Railway Gazette*, January 27, 1961.)

The value of marshalling yards in the efficient operation of freight traffic has been appreciated for many years and the first improvement was the use of gravitation introduced towards the end of the last century. Points were manually operated and brakesmen employed to check wagon speeds, either by working the hand brakes or by the use of skids. The next step towards mechanisation was the power operation of points from a central position and the installation of retarders to displace the dangers accompanying manual braking. At the present time there are several countries which have large marshalling yards with centrally controlled power-operated points and retarders and although these functions are worked manually more efficient operation is obtained. In some of the later installations some of the most modern techniques of automatic control have been introduced.

Sorting sidings.

The portion of a marshalling yard concerned with the sorting of freight trains extends from the reception lines, down an incline known as a hump and then to the sorting or marshalling sidings. On the arrival of a train in the sorting sidings it is uncoupled into single wagons or groups of wagons (called « cuts ») according to destination. A cut list is prepared and the train is pushed slowly forward to the summit of the hump down which the single wagons or cuts travel, through points and retarders, towards the end of the track space available in the sorting sidings. In its journey from the hump summit to its destination in the siding, a wagon passes through several points, which determine its destination and also through retarders, regulating its speed in relation to other cuts, to reduce the possibility of overtaking. The process also has regard to its destination to ensure that it arrives there at not greater than the desired buffing speed.

Centralised sidings.

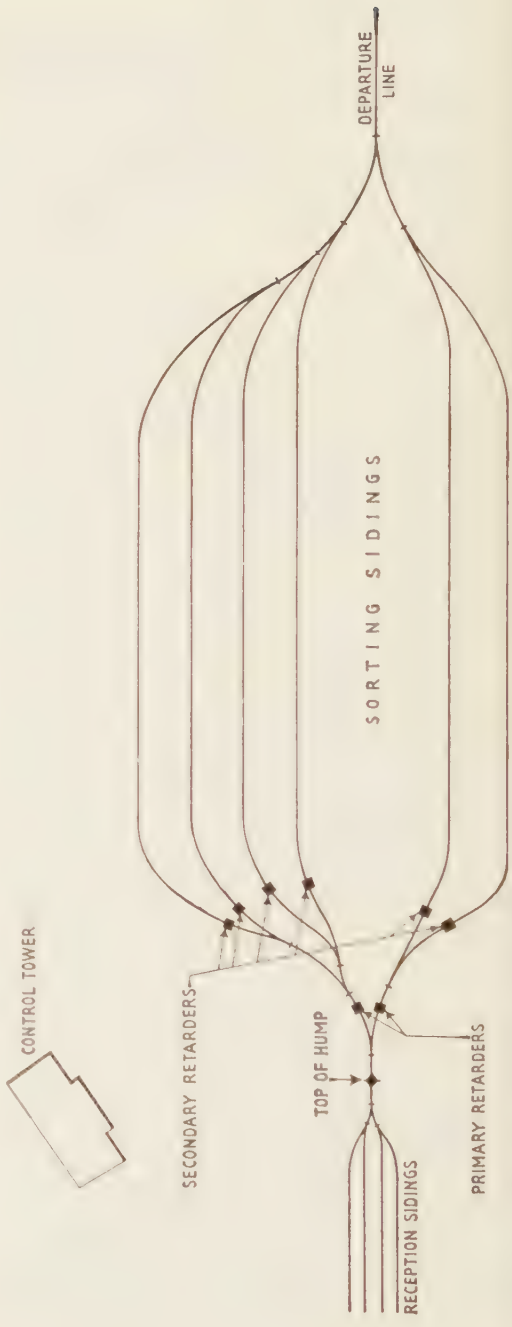
Centralised operation of power worked points in marshalling yards has been in use for many years together with track circuits to prevent them being moved while a wagon is travelling over them or is in close proximity. Some of these yards are at Banbury, Rogerstone, Mottram, and Severn Tunnel.

The object of installing retarders in the point area is to absorb the excess energy of wagons with a low rolling resistance and to release all wagons into their respective sidings at a speed which allows them to reach their destination at a safe buffing speed. In yards using primary and secondary retarders they are controlled so as to perform the subsidiary function of making the separation time between cuts or wagons of dissimilar running characteristics more uniform, thus making it less

possible for wagons to overtake each other in the switching zone.

The principal reason for having multiple retarders is an economic one, as for every foot of retarder which is useful in the primary, an equal amount is saved from each secondary retarder to which it leads. In all countries the majority of mechanised yards have retarders manually controlled by operators in a centrally situated control tower. Sometimes the operator is informed of the total weight of each wagon and by observing how it is running, and from his knowledge of where it should travel in a siding, he releases it at a speed which he assesses by visual estimation. Wagon chasers are employed to apply the hand brakes on wagons in cases where they have received insufficient retardation. In these cases technical aid is essential if operating efficiency is to be improved.

Many methods to assist the work of the retarder operator have been tested and the most satisfactory means so far employed and one that is now in fairly general use, is the application of a shortwave electromagnetic radiator and receiver to measure the speed of a wagon continuously during its approach to, and passage through, the retarder. This is sometimes termed Doppler Radar and by means of this equipment the speed of a wagon can be conveniently measured from the Doppler effect observed by comparing the frequencies of the wave transmitted from the radiating aerial and that of the reflected wave received back from the surface of the moving wagon. Such equipment was first used in Great Britain at Thornton Yard of Scottish Region, British Railways, to obtain automatic speed control of wagons from pre-selected release speeds for all primary and secondary retarders. Later at Temple Mills, Eastern Region, British Railways, for measurement of rollability and automatic speed control of the primary retarders. A later installation is at Margam Yard, Western Region, British Railways, for speed measurement and automatic retarder control. The operating functions which are to be included in a system of automation for the marshalling of wagons when they



are ready to be moved from the reception sidings to the sorting sidings are, in order of sequence :

1) the cut list giving the siding destinations of the cuts of wagons. This forms the humping programme for the train and must be delivered to the control centre;

2) when humping commences the programme 1) has to be read and several successive items memorised as several cuts are in the switching zone at the same time;

3) each cut on the programme has to be weighed if this is not given on the cut list and its rolling characteristics determined as far as possible;

4) each cut has to be guided to its correct route as it proceeds from summit to siding;

5) each destination has to be measured to show how far the cut has to travel;

6) primary and secondary retarders have to be operated in such a manner that successive cuts do not overtake, and the release speeds from the secondary retarders must be such that the cuts reach their destination at a very low and safe buffing speed.

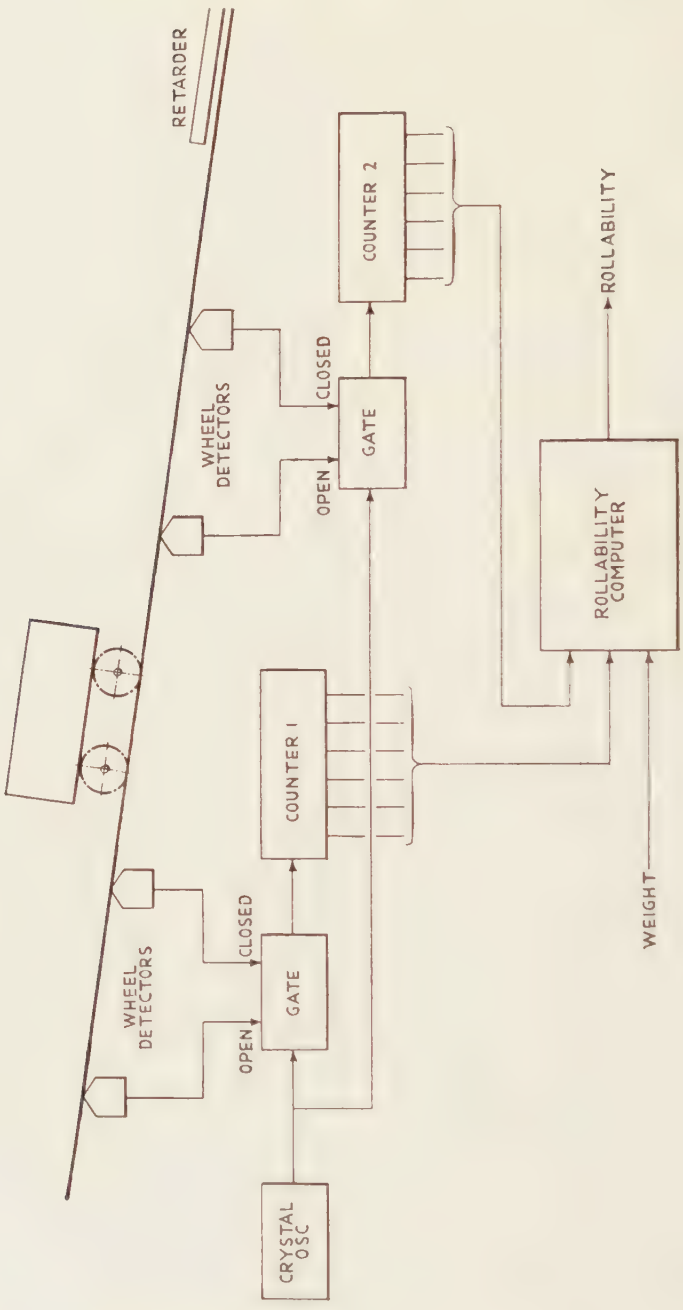
In a fairly busy yard an operator would be expected to deal with some 100 cuts an hour, or about 200 000 programmed items a year. Each cut has to be identified, its destination examined, its running characteristics found and its speed regulated. Even with the aid of automatic route setting, but without any aids to braking, an operator has to perform about 3 000 separate operations during each turn of duty in the marshalling of wagons. A miscalculation of any one of these would result in an error of performance which may require later correction even if it does not result in damage. When these operations are performed manually the work becomes dependent on intuition.

Wagon chasers.

It is unreasonable to expect a very high degree of accuracy even from the best operators and in order to cater for the operator's error of judgment, chasers are essential. These men do what they can to prevent collisions, when wagons are travelling too fast in the sidings. They are unable to take any action with retarded wagons which have stopped short and these have to be pushed up later by a locomotive which also corrects wrong shunts. Despite these difficulties, it should not be assumed that yard operation in the past has in all cases been of an inferior kind. With automatic route setting, manually controlled retarders, good operators and wagon chasers, with an efficient system of communication between the operators in the control tower, the hump engine driver and the chasers, many yards are capable of handling heavy traffic rapidly and with a low damage rate. The performance of these yards is entirely dependent on the quality of the manpower available and as it is now increasingly difficult to obtain suitable men, other means have to be found. These methods of automatic control, requiring the minimum of personnel, will now be considered.

Automatic control.

The manner in which these are employed is the result of an appreciation of the overall operating requirements, a partial knowledge of the variations of wagon characteristics to be encountered and considerable prior experimentation and testing of equipment under conditions as nearly comparable as possible with the intended installations. Automatic operation can be partial or complete. In the former case some manual operations are retained, in the latter, they are not. The yards on British Railways employing automatic operation at the present time are, in order of their completion, Thornton Yard, Scottish Region; Temple Mills Yard, Eastern Region; and Margam Yard, Western Region. All these yards have automatic point operation. Thornton Yard employs automatic operation of primary and secondary retarders according to pre-set release speeds manually set by the retarder operator. Temple



Automatic retarder control equipment for measurement of rollability.

Mills Yard uses automatic control of the primary retarders only and manual control of the secondary retarders. Margam Yard uses automatic control of all retarders and is the only one of these yards which is fully automatic.

The basic functions of a fully automatic yard are :

1) the setting up of a cut list programme;

2) the conversion of the programme into wagon route information for automatic point operation;

3) a measurement of the state of occupation of sidings in the marshalling yard before humping commences and a means of changing this information for each siding as wagons travel into them;

4) a measurement of the axle loads from which the weight category of cuts can be determined, unless this has already been given in the cut list;

5) a measurement of wagon rollability suitable for predicting the performance of a wagon or cut after it leaves the last retarder to its destination:

6) a means of combining the results of 2), 3), 4) and 5) above and computing therefrom the desired speeds at which cuts should be released from the retarders;

7) a means of measuring continuously the speed of a cut as it approaches and passes through a retarder;

8) a retarder and control system capable of responding to the results of 6) and 7) above;

9) a means of signalling to the humping locomotive to start and stop and at what speed it should push the wagons over the summit;

10) means of assuming manual control of points and retarders and thus overriding the automatic control of these when necessary.

These basic functions are provided in the following manner. The cut list programme originates from an examination of the wagon labels while the train is in the reception sidings, from where it is either transmitted to the central office directly or in some cases by radio transmission. Alternatively, the siding destination is chalked on the front of the wagons and read from them as the train is being pushed over the hump, and with this method the destination programme is prepared cut by cut as they pass the operator who reads the numbers.

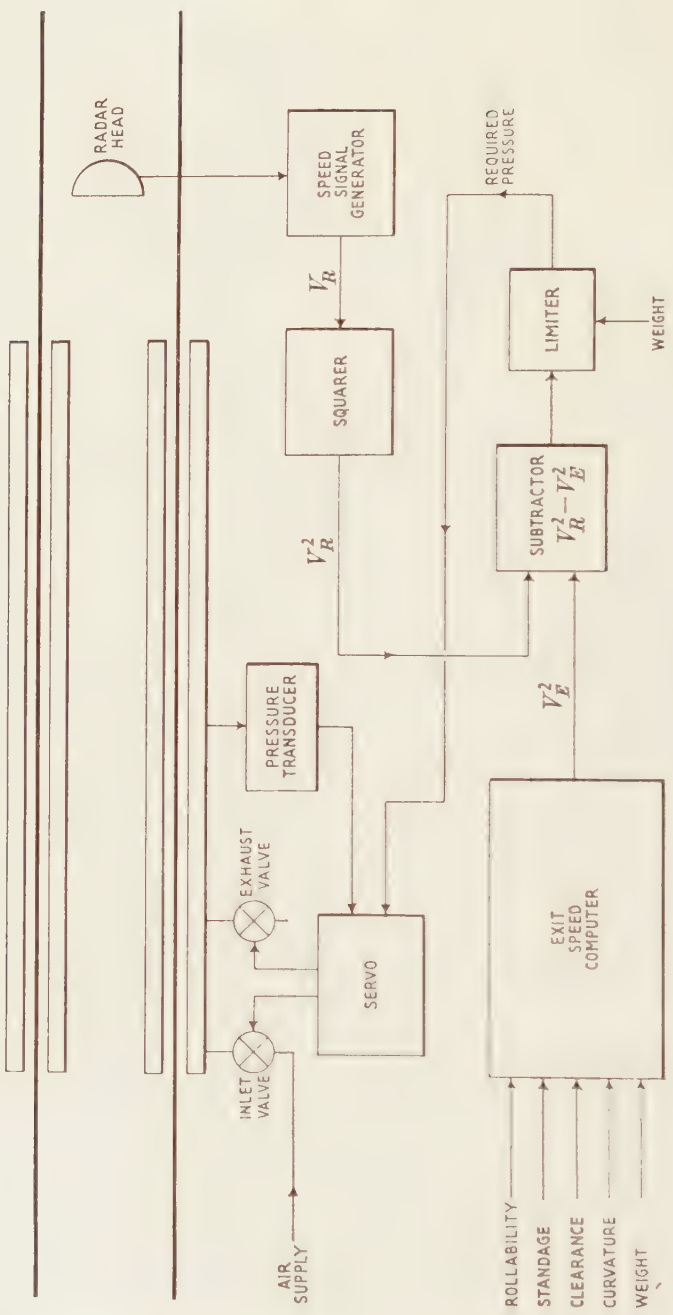
Train programme.

By one method a cut list can be delivered to the control tower operator, who then sets up the programme by depressing appropriate buttons corresponding to the destinations. At Thornton Yard a whole programme for a train of 48 cuts can be stored before humping begins. At Margam Yard the cut list when received in the control tower is typed in a tele-typewriter and repeated to several offices, and at the same time a perforator prepares a paper tape. When a train has been selected for humping, the tape for that train is placed in a reader which converts the teletype code into binary code suitable for feeding into the automatic point storage and setting relay network. The tape performs the programme store which with other methods require relay groups for this purpose.

The running distance into a siding is part of the total running distance of a wagon after the last retarder and one method of obtaining a measurement of this is to sub-divide the siding by means of track circuits and to subtract from the distance so given a definite length for each wagon which travels into the siding thereafter. The siding length can be corrected whenever a wagon fails to reach its destination.

The axleload is measured by inserting in the track a specially prepared section of rail having a slotted web and contacts to indicate load categories according to the amount of deflection of the rail.

Wagon rollability should include all fac-



Automatic retarder control equipment for variation of exit speed.

tors which determine the free running characteristics of a wagon or cut and is dependent upon track curvature, wagon weight, journal and flange friction. Some of these factors are difficult to measure accurately and with sufficient assurance that the results are suitable for predicting the performance of a wagon throughout its travel from hump to siding destination. Tangent rollability gives the most reliable measurement for this purpose and can be measured in various ways as the wagon travels freely over a known section of track. One method is to measure the times taken to travel over given measuring sections and therefrom to calculate the change in energy of the wagon between the measuring sections. This is then used to compare the difference of energy with the difference of elevation of the measuring sections and to modify the result according to the wagon weight to cater for rotational energy, finally storing the result as an analogue voltage for use in the computer. Another method is to measure rollability on a known tangent track by differentiating the speed signal of a doppler radar observing the wagons over the measuring section and storing the result as an analogue voltage. Curvature rollability can be measured similarly over a measuring section of known curvature by either of the above methods. The number of places where rollability measurements are made is a matter for serious consideration. If a satisfactory measurement can be made between the hump and the first set of points only one measuring section will be required for the whole yard and the results can be stored and passed forward to the primary and secondary retarder speed control system. The alternative is to have rollability measurements made on the approach side of each retarder. By the former method the distance from the summit to the siding clearance points is greater than that required for the latter method and some increase in retarder capacity will be necessary on this account. The amount of instrumentation with the former is less than with the latter, although it can be considered an advantage to have what amounts to a separate rollability computer for each group of sidings in the latter method and thus again some increased insurance against systematic faults or complete failure of the measuring equipment. At Margam the latter system has been used. At Temple Mills two antennae are situated on the approach to the primary retarders. One of these measures the velocity of the wagon as it approaches the retarder and from which a rollability measurement is obtained, while the other measures the velocity of the wagon as it passes through the retarder.

At Margam, inductors on the approach to the retarders are used for rollability measurements. Similar groups of inductors are situated on the approach to the secondary retarders for the same purpose.

Determination of release speeds.

The retarder release speeds are determined by analogue computers which consist of a combination of potentiometers and operational amplifiers which perform accurately and quickly the processes of addition, subtraction, multiplication and division, by which an equation of energy or motion of a wagon is solved. The release speed from the primary retarder is calculated to obtain approximately equal running times of single wagons to the secondary retarders and thus to reduce the possibility of wagons of different rollability overtaking one another. The release speed from the secondary retarders is calculated to allow wagons to travel to their destination and to arrive there at a safe buffing speed. This calculation must therefore include the losses of energy due to travel in the siding, and around any curves which may exist between the retarder and the tangent track, and the energy gained from any descending gradients. The resistance offered by curves, or the curvature rollability, can either be measured on a known curve for every wagon and the result used to obtain a factor assumed to be sufficiently accurate for calculating the energy losses of that wagon for all curves, or, alternatively, as the result of tests performed on

the actual curves, a value of curvature resistance can be found and added to the other losses of energy for each siding. After all these factors have been fed into the computer a result is given in the form of a highly stabilised voltage as a measure of the energy a wagon or cut should have when it is released from the final retarder.

Comparison of speed.

The retarder speed having been determined as the wagon is approaching a retarder, a means of comparing it with the actual wagon speed is required so that the proper retardation can be applied. The means employed is to direct a concentrated high-frequency electro-magnetic beam towards the wagon and to collect the reflection of this beam and to compare the frequencies of the transmitted and reflected signals. This is the Doppler Radar and it provides a continuous measurement of the wagon speed while the wagon is in the path of the beam. The transmitter and receiver form a single unit which is placed in the track and consists of a parabolic or hornshaped antenna energised from a v.h.f. source. At Thornton Yard the frequency of the radar system is approximately 3 700 megacycles per sec which gives a Doppler signal of 11 cycles per sec. per m.p.h. wagon speed. At Margam the frequency is 10 700 megacycles per sec. which gives a doppler signal of approximately 32 cycles per sec. per m.p.h. wagon speed.

The retarder control system consists of a unit into which is fed the information giving wagons speed as determined by the radar unit and the desired leaving speed which has been computed. The retarder is then applied at a pressure sufficient to accomplish the desired retardation. The maximum pressure which can be applied to a wagon is dependent upon the weight category into which it is placed by the weighing treadle, as in non-weight automatic retarders excessive retarder pressure can cause the wagons to ride out of the retarder and proceed unretarded. The control system must be sensitive, and capable of reducing the retarder pressure as the actual wagon speed approaches the leaving speed.

The humping speed of the pushing locomotive is not automatically controlled, but the speed at which the wagons pass over the hump summit is an important part of the overall operation. If wagons are pushed over too slowly obviously the humping operation will take longer than it should do. On the other hand, if wagons are pushed over too quickly it is possible for successive cuts to overtake before these have been correctly routed. A wrong shunt then results. The correction of wrong shunts can easily consume very much greater time than the apparent time saved by attempting to hump quickly, even if it does not result in damage. Means, therefore, are provided to indicate to the humping locomotive the speed at which it should push the wagons over the hump and this is done either by installing a fixed signal on the wayside or a signal in the locomotive cab. At Margam, cab signalling has been employed and a three-position indicator is placed in the cab of the locomotive, pick-up coils being placed over the running tracks at the ends of the locomotive. Audiofrequency signals are superimposed on the track circuit of the reception siding holding the train to be humped, and when the locomotive is attached to the end of this train it picks up from the track the speed signal which the operator in the tower has selected for that track. The principal signal in the driver's cab is a visual representation of a position light signal which would be placed on the wayside and which gives a continuous signal throughout the reception lines to the hump summit. An audible signal is also given to indicate any change of signal initiated by the yard operator in the control tower.

Protection against failure.

To allow for the possibility of failure of any of the automatic equipment and to allow an operator to assume an overriding control of points and retarders for any reason, the control panel situated in

the control tower is equipped with switches and buttons to allow this to be done.

What has already been described are the methods of automatic control and the means employed for effecting them, from which it will be apparent that many variable quantities are concerned with the overall operation. The overall operating result depends upon the accuracy with which the performance of a wagon after it leaves the last retarder can be predicted from previous measurements. It is useless to measure quantities to a very small margin of error if the possibilities of prediction are subjected to a large margin of error. Experience so far indicates that with free-running wagons consistently good operation can be achieved, the result being that the time taken for pushing down wagons in the marshalling sidings, although this so far cannot be said to be eliminated, is considerably reduced, and with more consistent running and accurate control of the wagon speeds damages due to high speeds in the marshalling sidings have been greatly reduced. The principal difficulty encountered has been the performance of the wagon itself when it is found that wagons have dragging brake equipment or the brakes bind when the wagon passes round curves. No amount of automatic equipment of the type which has been described can ensure that these wagons are run sufficiently far into the marshalling sidings or even reach the clearance points.

Summarised from a paper read before the Institution of Railway Signal Engineers on January 11, 1961.

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Class yards : A progress report.

(*Railway Signaling and Communications*, February 1961.)

In the last decade over 45 modern classification yards have been equipped with automatic switching and automatic retarder controls. Operation and maintenance of these automatic yards has proved successful. However, problems do arise to impede maximizing the benefits of automatic yard operation. The following discussion reflects current thinking among railroad signal, communications and operating officers on some of the problems in the operation of automatic retarder classification yards.

In 1950 automatic switching was introduced, and three years later automatic retarder controls made their debut. The combination of these controls has produced the modern automatic retarder classification yard. Since 1950, automatic switching and automatic retarder controls have been installed in over 45 new or modernized retarder classification yards. Six such automatic yards are now under construction and four others are in the planning stage, with construction starts scheduled for this fall.

When automatic yards are discussed by railroad men (signaling, communications and operations), the following topics always receive serious attention and healthy debate : *Keep management informed about a yard and its operation; advantages and disadvantages of the modern classification yard; humping rate, including the length and type of cuts to be handled; impact recorders; skates or mechanical retarders; maintenance; and the training of employees.*

« To get a good operation you've got to keep management informed », states a signal engineer. « You take management into your confidence in the preliminary planning for an automatic yard. Continue this confidence and close liaison through the construction and installation phase and long after the yard has been in service. You have to keep management informed about what they can expect from an automatic yard, as well as what the yard cannot accomplish. In this way you get a smooth operation, in which disappointments are kept to a minimum. Don't forget to include the traffic department, because those fellows can really use the automatic yards' benefits as a selling tool in securing more business for the railroad. »

A major point made by proponents of automatic yards is that the limitations of these yards should be clearly outlined, as well as their advantages. *A first limitation* is that a daily minimum of 1 200 to 1 500 cars requiring classification is necessary to economically justify construction of an automatic retarder classification yard. *A second limitation* is that the automatic yard can be a road block in the movement of through freight. For example, all trains that pass through an automatic yard are put over the hump. This charge has less foundation today than five or six years ago. Many roads are now blocking cars at originating terminals. When trains enter the automatic yard, blocks of cars destined for the yard are removed. Cars already classified are added in a block to the train. Thus through trains are not completely reclassified at each retarder yard through which they pass.

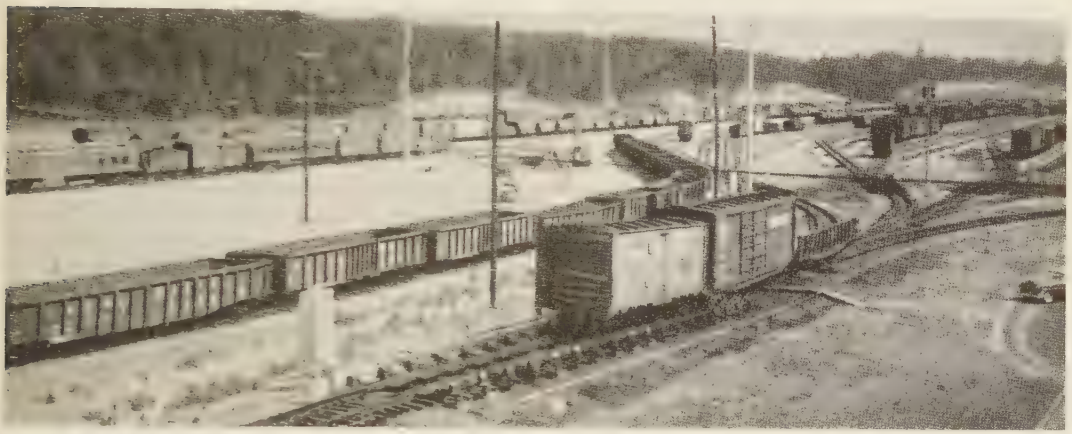
A third limitation regarding the automatic yard is its relatively high maintenance cost when compared with older yards. But modern yards have much more complex signal and communications equipment than was required in earlier yards. Considering the amount of electronic equipment involved, maintenance costs are not too high.

The major benefits to be derived from

the automatic yard are five-fold. The *first substantial benefit* is a reduction in damage to lading and freight cars. It has been estimated that freight claim payments for damage to lading total approximately $ 100 million per year on American railroads. According to many railroad officers, the most serious cause of damage to lading is rough handling of cars. In this respect the automatic yard plays an important part in reducing or eliminating excessive speed impacts and thus minimizes damage to lading. One railroad estimates that freight loss and damage claims have been practically eliminated at its nine-year old automatic yard, which classifies approximately 2 000 cars daily. Another railroad, which is handling 3 000 cars per day in one automatic yard, has cut damage claims by 85 % since the new yard has been in operation.

Second, automatic yards reduce the time spent in them by freight cars. They provide faster classification of cars and reduce congestion. Some examples of time savings follow: One railroad obtained a reduction of five hours in each of two automatic yards, compared to time spent by freight cars in the former manual yards; cars clear another road's automatic yard in an average of 8 h 49 min, as compared to the average of 20 h 29 min spent in a previously existing manual yard. The latter road also installed a new automatic yard in a terminal area. It previously took 27 h for a car to clear the terminal area, whereas it now takes 7 h with the new yard.

Third, a reduction in the amount of switching at other yards is accomplished by installation of an automatic yard. With the finer and faster classification available at an automatic yard, many roads are able to classify cars in station order or in spot loading dock order, so that local classifying is not required. In some instances, classifying at automatic yards has eliminated transfer moves to local yards. Industry switch runs can now originate at the automatic yard.



The fourth major advantage of an automatic yard is a reduction in yard operating expenses. One modern yard, with automatic controls and 40 class tracks, saved about $ 5 000 per week in per diem charges through reduced inyard delays. Another road with a modern automatic yard has experienced a net reduction in annual yard operating expenses of $ 625 743. Still another road has a reduction in annual operating expenses of $ 947 000 for an automatic yard.

A fifth benefit of an automatic yard has been in making land available for sale or for industrial development. One railroad which spent approximately $ 9 million

building an automatic yard, was able to regain approximately $ 2 million by sale of land formerly occupied by flat yards.

Practically every discussion of automatic yard operation includes the topic of humping rate. While the operating department would like to see a high humping rate, signal and yard men agree that experience indicates that a humping rate of four cars per minute (a 2-m.p.h. hump speed) will provide a good, steady rate of classification, minimize catch-ups or cornering of cars and reduce trimming. There are several factors which affect the humping rate. If you can get your splits « high on the hill » (hump), you will get faster separation of cuts. Therefore, you can hump at a faster rate. For example, if the order of cuts were to class tracks 1, 43, 9, 39, then the cuts could follow each other more closely than if the order were to class tracks 1, 2, 43, 41. One means of increasing this humping rate is for the hump conductor to glance ahead at his switch list to locate cuts going to widely separated tracks. He can alert the hump engineer to increase his hump speed for these cuts so that the « high splits » will take place.

One road obtains faster classification by reassigning class tracks each day. They obtain better utilization of class tracks — short track for a few cars, a long track for more cars. Thus they are often able to eliminate the need for two class tracks to handle a particular destination point. Therefore, they may not have to double over in pulling the class tracks when making up an outbound train.

Some railroads use pen graph recorders for making time checks of automatic and manual operation. In making these checks, one railroad found that on a first trick 611 cars were humped. Humping time was 3 h, 18 min, 43 sec and down time was 3 h, 23 min, 36 sec. Much of this down time was due to stopping humping operations to prevent overtakes. Of 611 cars humped in this first trick, six were humped using manual retarder controls. During a third trick 520 cars were humped, taking 3 h, 21 min, 9 sec. Down time was 2 h, 15 min, 51 sec. On this third trick more trimming was required than on the first trick. Of the 520 cars humped on the third trick, 85 were humped manually.

Basic to the humping rate is the size of the cut. One manufacturer's retarder controls require that cut lengths be limited to one or two cars. Roads utilizing this equipment have found no serious objections to this limitation. One general yardmaster remarked : « With humping one or two-car cuts we get a nice smooth operation. As far as this particular yard is concerned, we would have a very satisfactory operation with only one-car cuts. We haven't done this, but it would minimize even further the few errors in classifying due to the pin puller misreading the cut list. » He felt that the extra seconds required for single car cuts would be more than compensated for by the time required for trimming when a cut had been misdirected. One disadvantage of long cuts, according to one yardmaster (he calls anything over two cars a long cut) is that more time is required in separating the long cut from the following cut. Also, he said, these long cuts have a greater tendency for high impacts than shorter cuts.

As for lading of cuts humped, most roads are humping all cars except explosives, special long loads and some piggyback cars. One road, which has 57-ft. track circuits, uses automatic retarder control and manual switching when humping 65-ft. piggyback cars. This road, which normally uses no more than two-car cuts, does have occasional three-car cuts consisting of extra long loads on one car with two idler cars. For these cuts, they use manual retarder control.

Freight claim departments of most railroads are making use of impact recorders on freight cars. A consensus of informed opinion is that such usage is on a spot-check basis. General agreement is that an impact of 6 m.p.h. or more is a « penalty » impact, and too high. Practice on several railroads is to notify the signal department of all penalty impacts in automatic yards. One signal engineer reports that when he receives penalty impact reports, checks are made of the particular tracks in question. This is done by humping a cut three times

to the same class track, taking measurements of speed at several points. Another road makes monthly impact studies (using recorders) and speed checks at three locations : before and after the master retarder and at the end of the group retarders. They hump 10 cars down each class track. The average speed of the 10 cars at each location is used in retarder control adjustments. Also, keeping class tracks up to grade and maintaining the proper grade on the hump is essential in the automatic yard.

From the foregoing it can be seen that continuous adjustments of controls are essential to keep the modern automatic yard operating properly, hold down high impacts, and maintain a high rate of classification. General opinion is that at least one signal maintenance man and one communications maintenance man should be on duty around the clock at an automatic yard. Usually there are additional maintenance men on duty during the first or second trick.

Opinion generally favors the qualification of regular signal men for maintenance positions in an automatic yard. One road bulletins the maintenance positions early in the planning stage, so that the men can take part in the construction and installation of the complex electronic control equipment. These men usually attend schools held by the equipment manufacturers. Another railroad has a retarder technician who is responsible to the division signal supervisor. All signal maintenance forces in the yard are responsible to the retarder technician.

The complexity and large amount of electronic equipment, including an analog computer, in a modern automatic yard, accounts for the relatively high maintenance costs compared with those at older yards. The modern automatic yard is so vitally dependent upon the complex electronic and automatic equipment for operation, that high maintenance standards are essential. With investment in a modern automatic yard running into millions of dollars, a railroad cannot afford to have equipment failures.

Whether to use skates or inert retarders at the bowl end of the class tracks to stop cars usually creates a lively discussion. Most roads use one skate on each track, but some use two skates per track where they want to get a shorter stopping distance. One railroad has used a single-rail mechanical retarder, which is normally closed. When the class track is to be pulled, the motion of the engine through the retarder will « spring » it open, and it will stay open. To be placed in the retarding position, a power machine is used to drive it closed. Some roads are now using inert retarders instead of skates. « We have not found it necessary to use skates or inert retarders at our automatic yard », reports a signal engineer. « Continuous checks on impact speeds and the fine adjustment that we have achieved on retarder controls make skating unnecessary. We have not had any cars fould the ladder tracks at the bowl end of the class yard », he says.

Contrasted to cars that run away, occasionally there is the problem of skewed trucks causing cars to slow down and stop short on a class track. Several methods have been employed to straighten trucks after going around curves. One road has welded short sections of 3/8-in. rod on top of the rail on the approach to the turnout curves to jar the trucks back into alignment. Another road, which found this method unsatisfactory, ground eight or nine spots along 3 in. of the top of the rail to create a washboard effect. Other roads have used guard rails to provide the proper « kick » to align trucks.

While there are numerous problems encountered in operating an automatic yard, general opinion favors the construction of such yards and the trend in this direction would seem to indicate that four to seven automatic yards will be completed each year during the next decade. These yards are, of course, more complex than previous classification yards; however, the additional money required for their maintenance is more than justified by the economies resulting therefrom.

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[385 (09 .2]

OBITUARY.

Eugène MUGNIOT,

Honorary General Manager of the Paris Lyons & Mediterranean Company.

Former Member of the Permanent Commission of the International Railway Congress Association.

We have learnt with great regret of the death of January 26th last of M. Eugène MUGNIOT, former General Manager of the P.L.M. Company and former Member of the Permanent Commission of our Association.

M. Eugène MUGNIOT was born in 1883, at Pouilly-en-Auxois (Côte d'Or). After a brilliant scholastic career he entered the Polytechnical School, and then the National High School of Bridges and Roadways, from which he graduated as an engineer on the staff thereof.

In 1910, he entered the Operating Department of the P.L.M. Company. During the 1914 war, he was appointed a member of the liaison mission between the Army Headquarters and the main line railways. The work he accomplished on this mission earned him the cross of « Chevalier de la Légion d'Honneur ».

Before the end of the war, he was appointed Assistant Chief Operating Engineer, and at the age of 36 years, he became the Chief Operating Engineer of the P.L.M.

He devoted himself mainly to the problem of recruiting and training employees. For the empirical methods used until then, he substituted the organisation of schools either within the framework of the different regions or that of the different departments. In particular, he created two Higher Train and Traffic Schools, intended to train higher grades of employees.

At the same time as he devoted himself to training the staff, M. Eugène MUGNIOT did a great deal for the commercial activities of the railway by stimulating relations with the heads of economic centres.

In 1933, he was appointed General Manager of the P.L.M. Company.

On the 1st January 1938, when the S.N.C.F. was created, M. Eugène MUGNIOT was able to hand over to this organisation

a well equipped railway system, with well trained staff and outstanding managerial staff. His great achievements were crowned by his appointment in 1938 to the high honour of « Grand Officier de la Légion d'Honneur ». He retired from railway service on the 31st December of the same year.

Such was the career of this eminent personality of the French railways, which we have taken from the review « La Vie du Rail ».

M. Eugène MUGNIOT was elected a member of the Permanent Commission of the International Railway Congress Association in July 1934.

He took part in the Enlarged Meeting of the Permanent Commission at Brussels in 1935, as well as the Paris Congress in 1937, at which he was also a member of the Local French Organizing Commission. He always showed the greatest interest in the work of our Association and his affability endeared him to all his colleagues.

We offer his family our most sincere sympathy.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS.

[625 .14]

ANTIA (K. F.). — **RAILWAY TRACK. — Design, construction, maintenance and renewal of permanent way.** — One volume (5 1/2 · 8 3/4 in.) of 461 pages, with numerous figures and photographs. — 1960, Bombay; The New Book Company Private Ltd., « Kitab Mahal », 188-190, Dr. Dadabhas Naoroji Road. (Price : Rs. 24/—).

The 5th edition of this book, published for the first time in 1945, has just been issued. Numerous improvements have been made, and it has been brought up to date on many points.

After the classic historical introduction, the author calls attention to modern tendencies on the railway as regards comfort, productivity (efficiency) and economy; he shows how the higher speeds, smooth running requirements, and more powerful means of traction have led, in the case of the permanent way, to improvements to curves, the introduction of long welded rails, and mechanisation of maintenance work. More particularly from the point of view of Asiatic countries, he mentions the fast transport facilities now available for the maintenance gangs, as well as the elimination of sharp curves and steep gradients, thanks to making new sections of lines with many structures, often tunnels.

As he wished to offer a practical manual, especially for the employees of the Indian railways, Mr. ANTIA has not been content merely to write the usual descriptive chapters — which he has made extremely interesting — about the constitution and layout of the lines; he has gone into great detail about usual and new maintenance methods, especially those introducing a slight degree of mechanisation; he gives a detailed description of the methods of laying and renewing the track, and mentions the emergency steps to be taken in case of accident or flood.

A group of 48 pages, copiously illustrated, is devoted to a description of points and crossings, their use and their maintenance. Further on is a chapter dealing with the stressing and resistance of the track, as well as the quality of the materials used, especially the metals used for the rails (Thomas steel is no longer systematically criticised), sleepers and accessories; a few pages are devoted to wood and concrete sleepers, and the book ends with a chapter on signalling and the maintenance of bridges, which perhaps lies somewhat outside the scope of the subject, but is something no employee responsible for inspecting and maintaining the track should be ignorant of.

The book ends with a series of 17 appendices giving numerous useful data for Indian railway staff, which the author has skillfully avoided enumerating in detail in the text. It may also be added that he frequently refers to the usual practice in Great Britain and the United States of America.

In brief, « Railway Track » is a manual of great value from which railway staff of all grades may obtain invaluable information and useful data. Without sacrificing rigorous scientific reasoning, the author has been able to make his mathematical examples comprehensible, by giving them a slant in line with the special technique of the railway; in numerous cases, the formulae mentioned are followed by concrete examples from railway practice.

A. J.

MONTHLY BIBLIOGRAPHY OF RAILWAYS[1]

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(JUNE 1961)

[016 .385 (02]

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In French.

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Paris, Dunod, éditeur, 92, rue Bonaparte. Un fascicule de 100 pages de texte (24.5 × 30.5 cm) avec de nombreuses illustrations. (Prix : 14 N.F.)

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CAMP (S.).

Technique et organisation du contrôle du trafic et de la circulation par voie de radio et télévision.

Rapport VI du XXXIV[e] Congrès International (Copenhague, 1961), de l'Union Internationale des Transports Publics.

Bruxelles, Union Internationale des Transports Publics, 18, avenue de la Toison d'Or. Une brochure (21.5 × 27 cm) de 14 pages, illustrée.

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Les Centrales thermiques en 1960. Numéro spécial (mai 1960) de *La Technique Moderne.*

Paris, Dunod, éditeur, 92, rue Bonaparte. Un fascicule de 86 pages de texte (24.5 × 30.5 cm), abondamment illustré. (Prix : 14 N.F.)

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Commission de l'automation. *a*) **Introduction à l'emploi des machines électroniques dans les entreprises de transport public.**

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Bruxelles, Union Internationale des Transports Publics, 18, avenue de la Toison d'Or. Une brochure (21.5 × 27 cm) de 16 pages.

1961 629 .1

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Autobus modernes. Suspension pneumatique.

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Bruxelles, Union Internationale des Transports Publics, 18, avenue de la Toison d'Or. Une brochure (21.5 × 27 cm) de 50 pages, illustrée.

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Paris (5[e]), Eyrolles, éditeur, 61, boulevard Saint-Germain. Un volume (21 × 27 cm) de 100 pages, avec 34 figures. (Prix : 19 N.F.)

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Teil IV A, *Elektrotechnik*. 28. Auflage.

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(1) The numbers placed over the title of each book are those of the decimal classification proposed by the Railway Congress conjointly with the Office Bibliographique International, of Brussels. (See « Bibliographical Decimal Classification as applied to Railway Science », by L. WEISSENBRUCH, in the number for November 1897, of the *Bulletin of the International Railway Congress*, p. 1509).

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London : Percival Marshall & Co. Ltd., 19-20, Noel Street, W. 1. (Price : 12 s. 6 d.)

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McCALL (R.W.). — **Signal post telephones in the Scottish Region.** (1 200 words & figs.)

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1961 **656 .212 .5 (42)**
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LAYHE (A.C.). — **Mechanisation of permanent way works in the North Eastern Region.** (2 200 words, table & figs.)

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1961 **621 .431 .72 (492)**
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1961 **621 .431 .72 (73)**
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KUGEL (F.). — **For Diesel locomotive applications ... hydraulic drives have high capacity.** (2 200 words & figs.)

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First B.R. automatic level crossing barriers. (500 words & figs.)

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1961 **625** .162 (73)
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1960 **625** .17
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1960 **621** .33 (42)
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WILLIAMS (A.L.). — El **laboratorio británico de electrificación.** (600 palabras & fig.)

1960 **656** .2 (460)
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Las **inversiones ferroviarias.** (4 000 palabras.)

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BELLOMI (C.). — **Le reti complesse nell' algebra dei circuiti variabili.** (5 000 parole & fig.)

1961 **625** .5 (45)
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PASTORELLI (M.). — La **nuova funicolare di Capri.** (5 000 parole & fig.)

1961 **621** .3
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GIOVANARDI (G.). — Impiego del metodo grafico di Lehmann per il **tracciamento dei campi nella progettazione delle macchine elettriche.** (3 000 parole & fig.)

1961 **656** .254
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1961 **656** .2
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SANTORO (F.). — **Produttività tecnica e andamento economico delle ferrovie.** (2 500 parole.)

1961 **621** .138 (45)
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CHELLA (R.). — La **nuova rimesse automotrici** di Siena. (900 parole & fig.)

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SANTORO (F.). — Struttura economica dell' **organizzazione dei trasporti in Italia.** (4 000 parole & fig.)

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Il Libro Bianco del Governo Britannico sui trasporti. (2 500 parole.)

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BARBERIS (A.). — Considerazioni sulla **corrosione atmosferica dei metalli.** (1 700 parole & fig.)

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1960 **625 .25**
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POLESE (A.). — **L'impiego del freno a disco nel materiale ferroviario.** (Risultati di prove sperimentali.) (4 000 parole, tabelle & fig.)

1960 **656 (06**
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1960 **621 .33 (45 + 494)**
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DARD (M.). — Completamente **elettrificate le linee dirette da Genova per la Svizzera.** (2 000 parole & fig.)

In Netherlands.

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1961 **691**
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HAAS (A.M.). — **Schaaldaken van geprefabriceerd beton.** (3 000 woorden & fig.)

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1961 **656 .21**
Spoor- en Tramwegen, nr 6, 23 maart, p. 91.
VERBEEK (J.L.). — **Doorstromingsmogelijkheden in een knooppunt van rijwegen bij treinverkeer.** (1 000 woorden & fig.)

1961 **656 .2 (931)**
Spoor- en Tramwegen, nr 6, 23 maart, p. 94 en nr 7, 6 april, p. 118.
VAN BIJNEN (J.). — De **spoorwegen in Nieuw-Zeeland.** IV-V. (*Vervolg.*) (1 900 woorden & fig.)

1961 **621 .431 .72 (492)**
Spoor- en Tramwegen, nr 6, 23 maart, p. 96 en nr 7, 6 april, p. 115.
MAURER (J.J.), MOOLHUIZEN (Chr.) en VAN OMME (N.). — De **dieselelektrische drierijtuigstellen serie 111-125 van de N.S.** (*Slot.*) (3 500 woorden & fig.)

1961 **721 .1 (492)**
Spoor- en Tramwegen, nr 6, 23 maart, p. 100.
MEIJNEN (W.). — De **fundering van het post- en rijwielperron te Tilburg.** Diepte-verdichting van grond volgens het « Rütteldruckverfahren » voor de eerste maal bij de N.S. toegepast. (2 000 woorden & fig.)

1961 **385 .586 (492)**
Spoor- en Tramwegen, nr 7, 6 april, p. 107.
NOTEBAART (J.C.). — De **opleiding van het spoorwegpersoneel** bij de N.S. (2 200 woorden & fig.)

1961 **656 .2 (73)**
Spoor- en Tramwegen, nr 7, 6 april, p. 111.
Russen in de U.S.A. Veel gezien en gehoord; maar weinig dat beter is dan bij ons. (2 000 woorden & fig.)

1961 **656 .1 (44) & 656 .2 (44)**
Spoor- en Tramwegen, nr 7, 6 april, p. 121.
HUPKES (G.). — « **Rail-route** »-**systemen** uit Frankrijk. De open zelflosser. (1 000 woorden & fig.)

In Polish (= 491 .85).

Przeglad Kolejowy. (Varsovie.)

1959 **625 .23 = 491 .85**
Przeglad Kolejowy, août, p. 287.
PUZYNA (C.). — Résultats des **mesures du bruit survenant pendant le mouvement des voitures.** (2 600 mots & fig.)

1959 **656 .261 = 491 .85**
Przeglad Kolejowy, août, p. 297.
MICHALSKI (C.). — **Livraison individuelle et centralisée des marchandises de détail.** (3 300 mots & tableaux.)

1959 **621 .43 = 491 .85**
Przeglad Kolejowy, août, p. 304.
KRZETOWSKI (S.). — **Moteurs à combustion interne** dans les transmissions ferroviaires modernes. (5 200 mots & fig.)

1959 **385 (07 (438) = 491 .85**
Przeglad Kolejowy, septembre, p. 321-360.
Plusieurs auteurs. — Numéro entièrement consacré à l'organisation et aux travaux des différentes sections de l'Institut Central des recherches et du développement ferroviaire à Varsovie. (19 000 mots & fig.)

1959 **625 .215 = 491 .85**
Przeglad Kolejowy, octobre, p. 372 et novembre, p. 407.
SOBOLEWSKI (H.). — **Inscription dans les courbes et les aiguilles des voitures à bogies.** (3 800 mots & fig.)

1959 **621 .8 = 491 .85**
Przeglad Kolejowy, octobre, p. 384.
WOLFRAM (T.). — Comparaison des systèmes fondamentaux de **transmission hydraulique.** (2 500 mots & fig.)

1959 **385 .114 = 491 .85**
Przeglad Kolejowy, octobre, p. 394.
RATAJCZAK (K.). — **Les frais normalisés dans le transport ferroviaire.** (1 600 mots.)

1959 **656 .2 (438) = 491 .85**
Przeglad Kolejowy, novembre, p. 401.
WRÓBEL (S.). — **Développement de la technique ferroviaire** dans la période de quinze années de la Pologne Populaire. (3 500 mots.)

1959 **625** .143 .4 (438) = 491 .85
Przeglad Kolejowy, novembre, p. 411.
NEKANDA-TREPKA (L.). — **Soudure à l'arc des rails dans les voies sans joints aux PKP.** (2 000 mots & fig.)

1959 **691** = 491 .85
Przeglad Kolejowy, novembre, p. 424.
ADAMCZYK (K.). — Recherches sur la **propriété destructrice de la moisissure de l'huile de houille.** (1 400 mots, tableaux & fig.)

1959 **656** .235 = 491 .85
Przeglad Kolejowy, décembre, p. 441.
KRAJEWSKI (T.). — **Problèmes d'un nouveau tarif marchandises** dans les transports ferroviaires. (3 300 mots.)

1959 **385** .114 = 491 .85
Przeglad Kolejowy, décembre, p. 455.
MICHALSKI (C.). — Méthode pour définir les **prix de revient du transport** dans le funiculaire à voyageurs. (3 100 mots & tableaux.)

1959 **625** .25 = 491 .85
Przeglad Kolejowy, décembre, p. 462.
STANKIEWICZ (L.). — **Freins électro-pneumatiques.** (2 500 mots & fig.)

In Rumanian (= 599).

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1959 **625** .143 .4 = 599
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DISLI (N.). — Problème des **joints de dilatation dans les longues barres.** (3 100 mots & fig.)

1959 **625** .141 = 599
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ENACOVICI (V.G.). — **Formation des sacs de ballast** et moyens d'y remédier. (3 500 mots & fig.)

1959 **624** = 599
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POPESCU (C.). — **Phénomène d'amortissement et de résonance dans les ponts ferroviaires.** (5 600 mots & fig.)

1959 **624** .3 = 599
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CIOCÎRLAN (N.). — **Réparation et consolidation des treillis métalliques des ponts** sans emploi d'échafaudage. (3 600 mots & fig.)

1959 **656** .221 = 599
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POPESCU (C.) et GRIGORESCU (N.). — **Résistance au mouvement des wagons.** (5 300 mots & fig.)

1959 **385** .5 = 599
Revista Căilor Ferate, juin, p. 305.
BOLOS (M.). — **Application de la science de psychologie au travail ferroviaire.** (2 600 mots.)

1959 **656** .222 .5 = 599
Revista Căilor Ferate, juillet, p. 343.
FRÎNCU (P.). — L'étude et l'élaboration du **graphique de marche** et du système de changement des équipes. (2 900 mots, tableaux & fig.)

1959 **621** .31 = 599
Revista Căilor Ferate, juillet, p. 350.
SOR (C.). — **Equipement des lignes aériennes avec un système de transmission à courants porteurs.** (3 400 mots & fig.)

1959 **625** .26 = 599
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GIUREA (G.). — **Réduction du temps d'immobilisation des véhicules pendant leur réparation** grâce à la propagation et le perfectionnement de la méthode de la réparation par chaîne. (3 200 mots.)

1959 **656** .211 (498) = 599
Revista Căilor Ferate, juillet, p. 373.
MITRAN (G.). — **L'évolution de la Gare du Nord à Bucarest.** (2 900 mots & fig.)

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1959 **625** .141 = 599
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1959 **621** .39 = 599
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PERCIUN (N.). — **Théorie de la transmission des informations** à l'aide des canaux électriques. (4 500 mots & fig.)

1959 **625** .143 .4 = 599
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ANTONESCU (I.). — **Soudure de rails par étincelage électrique et pression.** (4 000 mots & fig.)

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GOILAV (E.). — **Réglage des circuits de voie.** (2 300 mots, tableaux & fig.)

In Russian (= 491 .7).

Pout' i Poutyévoïé Khosiaïstvo. (Moscou.)

1959 **625** .142 .2 = 491 .7
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FOMINE (E.D.). — **Automatisation des chantiers d'imprégnation de traverses.** (500 mots & fig.)

1959 **656** .2 = 491 .7
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ALBRECHT (W.G.). — **Les longs rails.** (1 700 mots, tableaux & fig.)

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1959 **625** .144 = 491 .7
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FÉDORTCHÉNKO (R.Y.). — **Pose de la voie sans joints.** (1 100 mots & fig.)

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PYÉRCHINE (S.P.) et collaborateurs. — Observations sur la **stabilité de la voie sans joints.** (800 mots & fig.)

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Pout' i Poutyévoïé Khosiaïstvo, octobre, p. 12.
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1959 **625** .141 = 491 .7
Pout' i Poutyévoïé Khosiaïstvo, novembre, p. 2.
BLOKHINE (K.A.). — Problèmes de la mécanisation du **nettoyage du ballast.** (1 600 mots.)

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1959 **625** .141 = 491 .7
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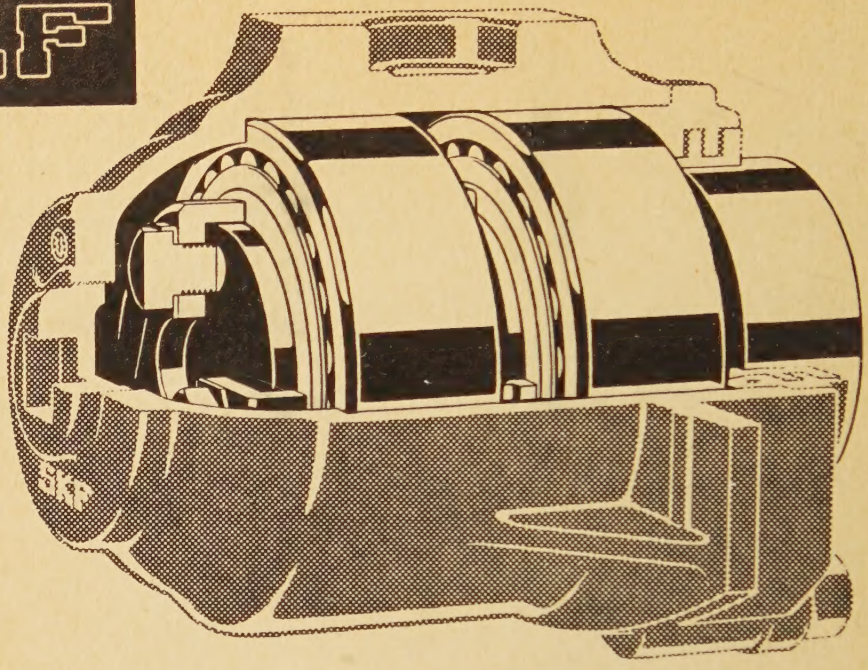

THE ULTIMATE AIM IS 100% ROLLER BEARINGS

At a meeting of Nordiska Järnvägsmannasällskapet (The Scandinavian Railwaymen's Association) in Oslo on 5th—6th May, 1959, a lecture was given entitled "Solid or built-up wheels". The following quotation from this lecture was published in the November 1959 issue of the Nordisk Järnbanetidskrift (Scandinavian Railway Journal) :

"Defects which have caused us most trouble in Sweden are hot running with plain bearings, cracked wheel seats, loose tyres, and flats on the tyres. Measures taken during the 1950s resulted in the number of cases of hot running being reduced considerably, from 9.3 goods wagons per million wagon-axle miles in 1951 to 0.6 in 1958. This favourable development was largely brought about by substantial investments in conversions from plain bearings to roller bearings. The ultimate aim is 100% roller bearings.

It was hardly necessary to calculate whether or not this would be economic, since this was self-evident in the light of the following advantages which weigh heavily in favour of roller bearings :

1) The costs arising out of normal hot running and of severe hot running resulting in broken journals and derailments are reduced.
2) Periodic lubrication of bearings between overhauls is no longer necessary.
3) The interval between overhauls of goods wagons has been increased from 3 to 4 years.
4) Wheels fitted with roller bearings have less frictional resistance."

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